New Scientist

WEEKLY 12 April 2025

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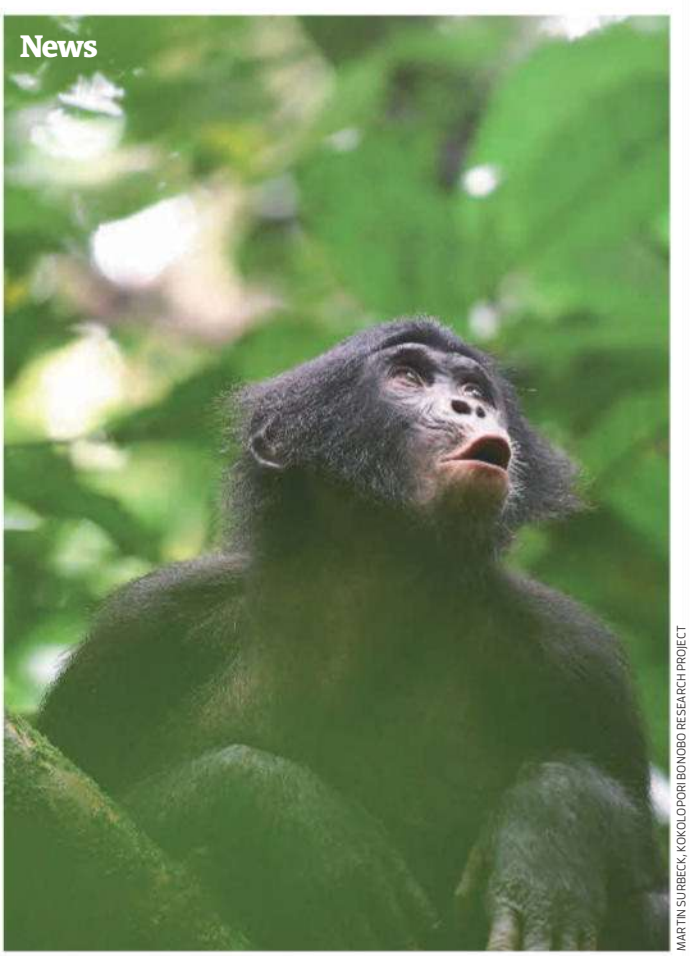

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Instant Expert

Consciousness and the mind-body connection

Discover the intriguing links between our physical and mental worlds, such as the strange effects of placebos and nocebos, and interoception – our ability to sense the body's internal signals. Join six world-leading experts at London's Congress Centre on 26 April to find out what this all means for our future health and the mysteries of consciousness.

newscientist.com/events

Tour

Exploring Darwin's Galapagos: Ecuador

Sitting in the Pacific Ocean, the isolated volcanic archipelago of the Galapagos inspired Charles Darwin's theory of evolution. Join marine biologist Jo Ruxton on a cruise around these 19 islands, offering the chance to see a plethora of wildlife, from marine iguanas to Galapagos tortoises. This eight-day tour starts on 14 July 2025 and 24 August 2026, and costs £7999.

newscientist.com/tours

Podcast

Weekly

The team discuss the oldest ivory artefacts ever found, which are 400,000 years old, predating *Homo sapiens*. Hear about an inadvertent solar geoengineering experiment and what this means for similar projects that are already in the works. Plus, learn how it is possible to give plants a kind of skin graft – and why this can make them more resistant to pests and diseases.

newscientist.com/nspod

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Galapagos cruise Observe a breeding colony of marine iguanas

MATTHEW DOMINICK/NASA

Odysseus lander The moon is an ideal location for radio astronomy

Video

Redefining the second

Atomic clocks record time using microwaves to measure the frequency of quantum vibrations of electrons. They are the basis on which the second is defined. But a new kind of more accurate timepiece, called an optical clock, promises to change this definition. Accurate clocks are vital to synchronise the infrastructure we rely on, from banking to shipping.

youtube.com/newscientist

Newsletter

Launchpad

When Intuitive Machines's Odysseus lander recently fell over on the moon, most of its scientific instruments were rendered unusable. But one survived: ROLSES-1. Now, data from the instrument has been analysed and released, marking the first time radio astronomy has been performed from the moon.

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Podcast

"The tools made from mammoth tusks may have been used as toys or training pieces"

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The pursuit of usefulness

Governments so often miss where the value of science really comes from

WHAT does science get us? That's always the question from those who fund it, but not from those who do it. This tension is in full swing in the US right now, as the Trump administration takes a hacksaw to the scientific ecosystem. But it isn't new.

In 1969, as Robert Wilson was testifying before the US Congress to get funding for a new particle collider at Fermilab, he spoke on the topic. The senators were grilling him on how this scientific endeavour would contribute to national defence or help compete with Russia during the cold war. He answered: "It has nothing to do with the military... it has to do with: Are we good painters, good sculptors, great poets?... It has nothing to do directly with defending our country except to help make it worth defending."

The utilitarian view always misses that so many of the biggest and most important discoveries come from the unobstructed pursuit of knowledge. And the line from discovery to application to return on investment is rarely a straight one. Without Albert Einstein

"Many of the biggest discoveries come from the unobstructed pursuit of knowledge"

musing in the early 20th century on the weightlessness felt by a person in freefall inside an elevator, we wouldn't have his theories of relativity and we wouldn't have GPS – a technology that has revolutionised life around the world.

It is impossible to predict what purely scientific inquiry will lead to, which is why the destruction being done to science in the US is so short-sighted. But it is much easier to foretell what damage slashed funding will cause. Losing programmes to treat and prevent tuberculosis, malaria and AIDS will lead to preventable disease and death. Cuts at NASA, including vital climate studies on extreme heat and air pollution, will be felt for decades if not longer (see page 14).

After physicist J. J.Thomson discovered the electron in 1897, he famously said it was useful for nothing. What followed was the electric age, a century of unimaginable global progress built on this humble particle. What revolutionary age to come is being impeded now? ▮

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Weekend warriors
It might not matter when you do your exercise p16

LONDON ZOO

Entomology

Standing on the shoulders of giants

This image shows a recently hatched giant hooded katydid (*Siliquofera grandis*) resting atop an adult. While this hatchling may not yet live up to its name, adults can grow up to 13 centimetres long and weigh 20 grams, eating leaves to get so big. They are native to the rainforests of South-East Asia. This photo was taken at London Zoo, which has a breeding programme.

Quantum physics

How we see the same reality

An idea inspired by evolution may explain why two observers see the same non-quantum world emerge from the many fuzzy probabilities of the quantum realm, says **Karmela Padavic-Callaghan**

THE quantum realm is notoriously full of uncertainties, but observers like us still manage to agree on how we experience it in very concrete ways. A quantum framework inspired by evolutionary principles may explain how such consensus is possible – and now researchers have proved it mathematically.

When you look at objects in everyday life, you see them as well-defined and without any weird quantum features. "So, the question is, how can we connect this divide between quantum and classical?" says Akram Touil at Los Alamos National Laboratory (LANL) in New Mexico.

A framework called quantum Darwinism could make that connection. Proposed in 2000 by Wojciech Zurek, also at LANL, this uses a process similar to natural selection to show how we end up seeing a non-quantum world and agreeing on what it is like.

The quantum world is full of existential fuzziness: each quantum object is a cloud of possible states of being until it is measured or observed, at which point it assumes one well-defined, or "classical", state. Physicists have debated what mechanism causes this transition for decades. With quantum Darwinism, Zurek suggested that the states we ultimately see are somehow more robust than the rest in the cloud of possibilities – in the language of natural selection, these states are more "fit".

When a quantum object interacts with its environment, some of its possible states are destroyed, but the remaining states survive by replicating themselves. Thus, when you look at an object and see it as unfuzzy, you are really seeing one in the long chain of these copies.

In their new work, Touil, Zurek and their colleagues considered how much two observers could agree on the aftermath of this process. They studied a scenario where each observer only has access to a fraction of the object's environment and never the object itself. With such limited information, each observer could end up with a vastly different mental picture of the object.

"Quantum Darwinism may be able to explain why we see a non-quantum world with some quantumness"

To quantify the difference in their perceptions, the team calculated the observers' "mutual information", a number that captures the overlap between what each one learns about the object. For a broad class of objects and environments of different sizes, they found that the observers reach consensus on the non-quantum world they observe.

Jarosław Korbicz at the Polish Academy of Sciences says this fills in a detail that had so far been missing from quantum Darwinism, which he says is a "brilliant and necessary" framework for understanding how we interact with the quantum world. "Consider you and me are looking at something, let's say at my glass of water," he says. "There is a correlation between the glass of water and us seeing, and then the question is, 'Is there a direct correlation between me and you?' This work completes that picture." Specifically, the team found this correlation exists. "Although trivial in ordinary life, such questions are not necessarily obvious in the quantum world," he says.

Quantum environment

In addition to mathematical calculations, Touil and his colleagues worked with researchers at Zhejiang University in China to translate their work into an experiment. It used 12 quantum bits, or qubits, inside a quantum computer, with two of the qubits designated as the object and the remaining 10 as their environment. The researchers obtained preliminary data on how those qubits' quantum states change over time – and these results were consistent with the predictions of quantum Darwinism.

Touil presented the mathematical work and Kiera Salice at the University of Houston in Texas presented the experiment last month at the American Physical Society Global Physics Summit in California.

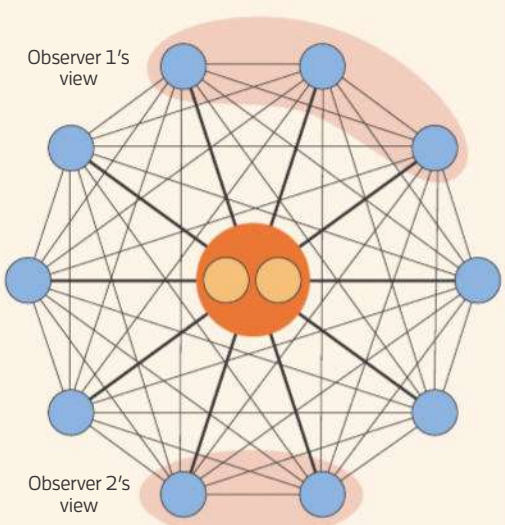
Touil says this is the biggest such experiment to date, but similar studies had also offered encouraging results in the past. Such experiments strengthen the case for quantum Darwinism as an explanation for how the quantum world becomes the world that we know, says Korbicz.

Gerardo Adesso at the University of Nottingham, UK, says the work adds weight to quantum Darwinism as a way of understanding how the classical world emerges from the quantum, but there is room for adding more detail. For instance, calculations could pinpoint not just how much observers agree on the classical world they observe, but the exact content of their observations. And the question remains whether any trace of quantumness can survive the process of reaching consensus, he says.

Touil also wants to go beyond qubits and explore how quantum Darwinism can explain the full richness of the physical world. For example, he wants to relate his team's work to quantum states of matter, which can be created in the lab with special materials or extremely cold atoms. In this way, quantum Darwinism may be able to explain not just why we see a non-quantum world, but also why that world still contains some examples of quantumness. ▮

Finding quantum consensus

How can two observers agree on what a quantum system (orange circle) looks like? Quantum Darwinism says that even if each observer's view (pink regions) only covers part of the environment (blue circles), they have enough information to come to the same conclusion about the state of the system.



Neuroscience

Largest mammalian brain map ever could unpick what makes us human

Helen Thomson

THE largest and most comprehensive 3D map of a mammalian brain to date offers an unprecedented insight into how neurons connect and function. The new map, which captures a cubic millimetre of a mouse's visual cortex, will allow scientists to study brain function in extraordinary detail,

"The neural activity from a portion of a mouse's visual cortex was recorded as it watched movies"

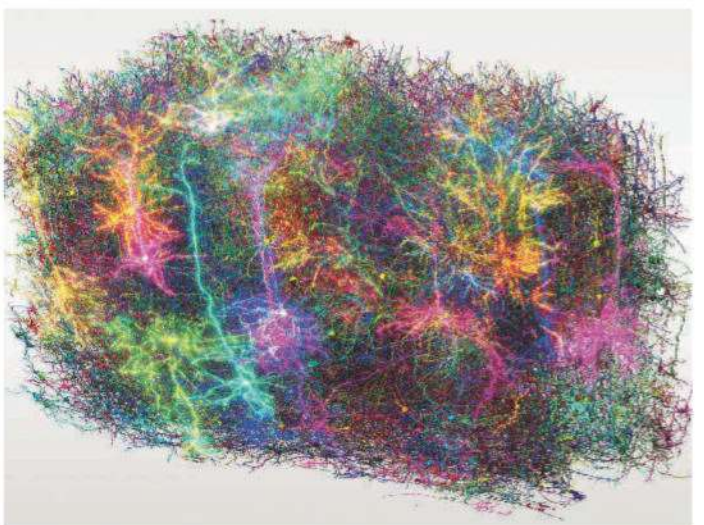
potentially revealing crucial insights into how neural activity shapes behaviour, how complex traits like consciousness arise, and even what it means to be human.

"Our behaviours ultimately arise from activity in the brain, and brain tissue shares very similar properties in all mammals," says team member Forrest Collman at the Allen Institute for Brain Science in Seattle. "This is one reason we believe insights about the mouse cortex can generalise to humans."

Uncharted territory

The achievement – something that biologist Francis Crick said in 1979 was "impossible" – took seven years to complete and involved 150 researchers from three institutions. It began with a team recording neural activity from a portion of a mouse's visual cortex, which was no bigger than a grain of sand, as it watched movies and YouTube clips.

Next, a second group dissected that same brain region, dividing it into layers 1/400th the width of a human hair, and took pictures of each slice. Due to the delicate nature of the structure, the slicing process couldn't be stopped for long, so the team took shifts.



THE ALLEN INSTITUTE

A representation of more than 1000 cells from the brain map

"We spent 12 days and 12 nights sectioning this millimetre cube of tissue into almost 30,000 layers," says team member Nuno da Costa, also at the Allen Institute.

From there, a third team used AI to trace all the cells and reconstruct each slice into a 3D map. "It was like asking AI to do the world's hardest colouring book," says Collman. "You have 100 million images in three dimensions and every single cell has to get coloured with a different crayon. The AI has to decide where one cell starts and the next one stops."

This data was finally combined with the functional activity recorded at the start of the project so that what the mouse was watching could be linked with the corresponding activity in the brain.

The resulting map illustrates the staggering complexity of the brain. Despite its diminutive size, it contained more than 200,000 cells with 4 kilometres of branches between them, and 523 million synapses joining the cells together.

The data is already challenging assumptions about how neurons communicate, revealing that they not only target nearby cells, but also actively hunt out other cells dedicated to processing the same visual stimuli.

Filling in the gaps

The researchers hope their map will bridge some of the gaps in knowledge between neural activity and behaviours, eventually helping unravel complex traits like intelligence. "It is ground-breaking work that will be invaluable to the scientific community," says Nathalie Rochefort at the University of Edinburgh, UK.

Beyond its immediate applications, da Costa says we might even be able to test theories of consciousness. "If someone has a theory of consciousness, they might be able to ask questions of this data, which could then support their theory or reject it."

The work builds on another study published last year that mapped every neuron in the adult fly brain – a breakthrough that has already revolutionised the field, says Rochefort. For instance, it has helped scientists better understand the circadian rhythms that affect everything from sleep to metabolism.

She says this new map will be incredibly beneficial, allowing researchers to make comparisons between it and other maps of different species to examine what cells, wiring principles and functional properties are specific to one species or conserved across several of them, "ultimately shedding light on what makes us human".

The project is published in a series of eight papers in *Nature* journals.

200,000
The number of brain cells contained in the map

523
How many million synapses join the cells in the map together

4
The number of kilometres of branches between the brain cells

Human evolution

Arabia's green history

Arabia had several humid spells in the distant past, which might help us retrace our ancestors' journey out of Africa, finds **Michael Marshall**

TODAY, Arabia is almost entirely scorching desert, but it has been green and lush several times in the past 8 million years. That means animals from Africa could have wandered into the area – potentially including early human relatives thought to have been confined to Africa.

"The deserts are turning on and off through time," says Michael Petraglia at Griffith University in Brisbane, Australia. "We have hippos coming out of Africa. Why not hominins?"

Previous research has shown that Arabia had rainy periods during the past 1.1 million years. During these wet spells, the peninsula had rivers and lakes that supported grasslands and woodlands. Modern humans and other unidentified hominins moved into the area during these hospitable times.

To extend the climate record further back in time, Petraglia's team sampled stalagmites and stalactites from seven caves in the Umm Er Radhuma formation in central Arabia. Because these are created by the flow of water into caves, they contain records of past climates.

The team aged them using two methods: uranium-thorium dating and uranium-lead dating. The uranium-lead dating is a significant advance, says Petraglia, because it allows the land-based climate record to be extended much further back in time. "It's just a game changer, because the dating could go back that far," he says.

The caves recorded four wet periods in the past 8 million years: 7.44 million to 6.25 million years ago; 4.10 million to 3.16 million years ago; 2.29 million to 2.01 million years ago; and 1.37 million to 860,000 years ago (*Nature,* DOI: 10.1038/s41586-025-08859-6).

We don't yet have fossil records to reveal what Arabian ecosystems were like during these humid periods, says Petraglia. But if the past million years is any guide, we can expect rich grasslands and woods around rivers and lakes, he says.

"Suddenly, we're starting to get a handle on how habitable this area might have been," says Anya Crocker at the University of Southampton in the UK, who wasn't involved in the study. She says the cave records probably give a good indication of conditions across Arabia as rainfall there is controlled by the monsoon, which operates on a continental scale.

> "It is possible that early hominins lived in Arabia when the climate was suitable"

It is also possible that the wet conditions extended into the Sahara desert to the west, says Petraglia. If so, there may have been intermittent green corridors spanning North Africa and Arabia. Crocker has also found evidence of wet periods in the Sahara over the past 11 million years: "These same arid-humid cycles, they seem to match up really nicely."

The study's 8-million-year timespan covers the entirety of known hominin evolution. The earliest hominins, like *Australopithecus*, are known only from Africa. Only members of our genus, *Homo*, are known to have lived outside Africa. The oldest known is *Homo erectus* from Dmanisi in Georgia, from 1.8 million years ago. There are also stone tools, made 2.1 million years ago by unknown creators, from Shangchen, China.

Petraglia says it is possible that hominins, including those before *Homo*, lived in Arabia when the climate was suitable. "The humid windows are telling us there's no reason why they shouldn't be," he says. The problem is that there is a huge gap in the Arabian fossil record, spanning from about 5 million to 500,000 years ago. ▮

ROBERT HARDING/ALAMY

The AlUla oasis is a green patch in modern-day Saudi Arabia

Health

Common artificial sweetener may have a bitter side effect

Grace Wade

PEOPLE report being hungrier after consuming the artificial sweetener sucralose and experience heightened brain activity in a region involved with appetite.

Artificial sweeteners, which sweeten foods and drinks without adding substantial calories, have become popular as awareness around sugar's health risks grows.

> "The brain registers the sweet, sugary taste, but doesn't detect other signals of fullness"

To look at their effects on hunger, Kathleen Page at the University of Southern California and her team analysed brain activity in 75 adults before and after they consumed water or a drink containing sugar or sucralose. The participants, aged 18 to 35, consumed each drink on separate days after fasting overnight and rated their hunger before and after. The researchers also tracked blood flow in participants' brains – a marker of neural activity – for 35 minutes after each drink.

On average, blood flow to the hypothalamus, a brain region involved in hunger, increased by about 3 per cent after participants consumed sucralose and decreased by around 6 per cent after they drank water or the sugary drink. Participants also reported feeling three times hungrier after drinking the sucralose beverage compared with the sugary one (*Nature Metabolism*, doi.org/g8982v).

This may be because, unlike sugar, sucralose didn't trigger the release of the hormones insulin and GLP-1, which tell the brain when food is consumed. Page believes sucralose causes a mismatch in the brain because it registers the sweet, sugary taste, but doesn't detect other signals of fullness. "That might, over time, make people crave these [sweet] foods," she says. ▮

Wind farm developers are worried about neighbours stealing their wind

Offshore wind farms can reduce the power generated by their neighbours – an issue that is growing more prevalent as turbines get bigger, finds **Madeleine Cuff**

IMAGINE you have just built yourself a lovely new house with an unobstructed view of some nearby mountains. But, within months, someone else starts building a home right in front of yours, blocking your view. A neighbourhood dispute looks inevitable.

A similar scenario is playing out across northern Europe with the rapid development of offshore wind farms. As the seabed becomes increasingly crowded with turbines, developers are becoming concerned that new wind farms could "steal" wind from existing sites.

The problem lies with wind farm wakes. "The job of a turbine is to rotate a set of blades that extract energy from the incoming wind. But, as you extract that energy, then you leave behind much lower energy," says Pablo Ouro at the University of Manchester, UK. That creates a region of "low-velocity wind", he says, which can extend for tens of kilometres.

The issue has become critical as more offshore wind farms have sprung up and turbines have become larger and more powerful, creating bigger wakes. At least a dozen disputes have broken out among clean-energy developers in the UK as they jostle to protect their wind resources from neighbouring projects, according to Sarim Sheikh, who previously led General Electric's offshore wind business.

"Wake effects are nothing new. It's been there since the very beginning of wind farm development," says Sheikh. "What has changed over the last few years has been the rapid scale of the growth in the size of wind turbines."

Estimates of the financial impact of wake losses vary. Research published last year by a team at the University of Bergen in Norway suggests wind farm wakes can extend up to 50 kilometres and cut wind resources available to downstream farms by as much as 20 per cent. Other estimates from researchers in the US suggest wakes could affect yields by more than 30 per cent in certain severe conditions.

MONTY RAKUSEN/GETTY IMAGES

Offshore wind farms can be affected by wakes from neighbours

Most in the wind industry work on the assumption that wakes can cut the yield of nearby wind farms by well below 10 per cent. "The big numbers are, in the main, taking an extreme, specific scenario," says Joel Manning at UK consultancy K2 Management, which conducts energy-yield analysis for wind developers.

30%

How much wake effects could cut wind farm yields, in severe cases

But even yield losses of a few per cent can have a huge impact on an industry working within increasingly tight margins. "This is something that is a worry, especially from an investment point of view and profitability of existing or future projects," says Ouro. Ultimately, financial uncertainty and reduced profitability could result in increased power prices and reduced capacity.

In the UK, the government wants to dramatically increase offshore wind power to make it the backbone of the country's future clean power grid. It has set a target to increase capacity from the 15 gigawatts currently in operation today to 43 to 50 gigawatts by the end of the decade.

Accurately assessing the impact of wake effects is therefore crucial for the UK's climate goals, says Ouro. "Net zero is not about how much capacity, how many gigawatts we install. It is how many gigawatt hours [of electricity] we can produce."

Last month, the University of Manchester launched a national assessment to try to quantify the problem for UK developments. Ouro is leading the 12-month project, which will work with offshore wind developers to model how wind farms set to be operational in 2030 will affect the yields of those currently generating electricity. It will be the first assessment of its kind in UK waters.

Test the waters

"The biggest outcome is that we can inform the future lease sites... so we can reduce the wake effects," says Ouro. That might mean tweaking the boundaries of wind farm sites to include larger "buffer zones" between neighbouring farms, for example, or changing the orientation of sites to reduce the wake effect. "If we were to provide information on where to put future turbines, if we improved that a bit, that would be a huge success, because that is a benefit for taxpayers and everyone," says Ouro.

But planners must strike a balance between maximising power output from UK waters and ensuring the country remains attractive to offshore developers. Other nations are watching the UK's response closely. "This is not just a North Sea issue. This is very much an international issue," says Eirik Finseråas at Norwegian law firm Wikborg Rein.

In the meantime, firms with sites already in development or under construction are battling it out in the planning and legal systems to protect their wind resources. Some are establishing "wind wake agreements" that might include compensation for affected wind farms, as well as agreements to design new sites to minimise downstream impacts.

Yet despite the concern over wind wakes, the UK remains a world-leading market for offshore wind developers, with favourable government policies and generous pricing contracts. For many, that is worth risking some trouble with the neighbours. ▮

Archaeology

Ivory objects a mammoth discovery

Oldest ivory artefacts may have been used to practise tool-making

Taylor Mitchell Brown

ARCHAEOLOGISTS excavating 400,000-year-old rock in western Ukraine have uncovered fragments of what could be the oldest human-made ivory objects ever found. These artefacts would have been too soft to use as cutting tools, but could have been used as teaching aids, the researchers suggest.

"If the interpretations are correct, they add to an apparently increasing appreciation of the intelligence of pre-modern humans," says Gary Haynes at the University of Nevada.

In the Southern Bug Valley, around 300 kilometres south of Kyiv, researchers discovered 24 pieces of ivory alongside putative hearths and artefacts of quartz and flint. Bones at the site indicate the presence of ancient horses, woolly rhinoceros and large feline species such as leopards or lions. The ivory probably came from *Mammuthus trogontherii*, a large species of mammoth common across Pleistocene Eurasia.

Bone tools have a deep history in the archaeological record, with the earliest examples being around 1.5 million years old. Ivory artefacts made of mammoth tusk, a much softer and more pliable material than bone, hadn't previously been found beyond about 50,000 years ago.

"Due to its softness, ivory does not provide a durable sharp edge like stone," says Vadim Stepanchuk at the National Academy of Sciences of Ukraine.

Given the age and location of the site, the pieces of ivory may be associated with early hominins like *Homo heidelbergensis*, says Stepanchuk. However, the site presently lacks fossil evidence to confirm the species, he says.

To better understand the ivory, Stepanchuk and his colleague Oleksandr Naumenko at the National Museum of the History of Ukraine subjected the fragments to microscopic and 3D analysis. Their results suggest 11 of the fragments show signs of having been deliberately chipped away by humans, while three pieces hint at a specific tool manufacturing technique in which a material is hammered over a rock anvil (*International Journal of Osteoarchaeology*, doi.org/pf3s).

Given their size and softness, it remains unclear what they would have been used for. Stepanchuk's team suspects it was to teach inexperienced group members, possibly children, how to craft tools. "The purpose wasn't to make a functional tool, but to produce something that simply resembled one – perhaps as a toy or a training piece," says Stepanchuk.

It isn't yet possible to rule out natural processes as the source of these fragments, says Paula Mateo Lomba at the Catalan Institute of Human Paleoecology and Social Evolution in Tarragona, Spain.

Haynes says many elephant species lose parts of their tusks while fighting.

Stepanchuk hopes researchers will uncover more ancient ivory pieces to clarify their potential role in early hominin history. "This site deserves further research," he says. "It offers a chance to better understand not only the deep human past, but also ourselves."

The flakes (inset) were made from the ivory of mammoth tusks

V PALES/ALAMY; VADIM STEPANCHUK

Animal behaviour

Cave spiders have a surprising use for their webs

SPIDERS known for elaborate circular webs have altered their spinning style in dark spaces to create apparent tripwires for walking prey.

Those that make circular webs are known as orb-weavers, and most of them trap mosquitoes, beetles and other flying insects in sticky spiral frame webs sparsely attached to outdoor structures, like tree branches. But European cave orb spiders (*Meta menardi*), which eat mostly non-flying animals like centipedes, slugs and other spiders, anchor their webs to cave walls using twice as many silk strands, which appear to vibrate when tripped by unsuspecting crawlers.

In 2021, Thomas Hesselberg at the University of Oxford and his team realised that cave spiders build smaller webs with fewer frame strands – those circling the web centre – and more radial threads extending out as anchors. It made Hesselberg wonder if the spiders were adapting their webs for a different capture technique.

To find out, Hesselberg and his colleague Emily Brannigan observed the feeding behaviour of female orb spiders in the Creswell Crags Archaeological Park in Derbyshire, UK, for six days. They released various prey – a mealworm, a large centipede and another cave spider – along the radial strands of the webs or near to them. When these animals triggered one of the anchor strands, the cave spiders ran along an adjacent strand towards them (*Ethology*, doi.org/pf3q). Vibrations from these "tripwires" were probably strong enough for the spider to sense from the middle of the web because there were fewer frame threads – which would have dampened the signal, says Hesselberg.

"This might be one of several tactics these spiders have evolved to adapt to feeding in caves"

The researchers suspect this might be one of several tactics these spiders have evolved to adapt to feeding in caves. "This indicates that they have a much wider flexibility in their foraging strategies than the orbs outside do," says Hesselberg.

Christa Lesté-Lasserre

Solar system

A new way to power moon bases

Karmela Padavic-Callaghan

FUTURE lunar bases could be powered by solar cells made on-site from melted moon dust.

Building items on the moon, using materials that are already there, would be more practical than shipping them from Earth. When Felix Lang at the University of Potsdam in Germany heard about this idea, he instantly knew what to do. "It was like, 'We have to make a solar cell like this, immediately'," he says.

Two years later, Lang's team has built and tested several solar cells with moon dust as an ingredient. The other key component is a crystal called halide perovskite, which contains elements such as lead, bromine and iodine, alongside long molecules made of carbon, hydrogen and nitrogen.

The team melted a synthetic version of lunar regolith – the layer of loose rocks and dust that blankets the moon – into "moonglass", which they then layered with the crystal to complete a solar cell (*Device*, DOI: 10.1016/j.device.2025.100747). They didn't purify the regolith, so the moonglass was less transparent than materials in conventional solar cells. But Lang says that the team's best prototypes still reached about 12 per cent efficiency in generating electricity. More conventional perovskite solar cells typically reach efficiencies close to 26 per cent; Lang says computer simulations suggest his team could reach that in the future.

In general, researchers agree perovskite solar cells will outperform more traditional silicon-based devices, both in space and on Earth. From the lunar standpoint, using perovskite materials is also attractive because they can be kept very thin, which would reduce the weight of the material to be transported to the moon. The team guesses that a solar cell with an area of 400 square metres would require only about a kilogram of perovskite. This is an impressive claim, says Ian Crawford at Birkbeck, University of London.

Not having to purify the regolith is similarly important, as it means no special reactors would be necessary. In fact, Lang says a large curved mirror and sunlight could create a beam of light warm enough to make moonglass. One of his colleagues already tested this on the roof of their university and saw signs of regolith melting, he says.

Nicholas Bennett at the University of Technology Sydney in Australia says that, while past studies tried to process lunar regolith into transparent glass, this is the first time that a solar cell has been shown to work with the less finicky moonglass. The challenge now, he says, is to make lots of moonglass outside the lab. Michael Duke at the Lunar and Planetary Institute in Texas says that manufacturing moonglass-based solar cells will require many advancements, from excavating regolith to connecting individual cells into arrays.

> "Using materials that are already on the moon is better than shipping them from Earth"

Lang and his colleagues are working on increasing their solar cells' efficiency. Ultimately, they want to expand the process to other dusty denizens of space. "We are already thinking, 'Can we make this work with Mars regolith?'" says Lang. ▮

Psychology

The games you played as a child stay the best

Jeremy Hsu

NINTENDO

Nintendo Switch players enjoy retro games such as Super Mario Advance

VIDEO gamers have especially strong nostalgia for titles and consoles that they played when they were about 10 years old – at least according to a study of Nintendo Switch users.

"Through playing older games, people can feel connected to who they were and how they were feeling at the time," says Nick Ballou at the University of Oxford.

He and his colleagues analysed 12,000 hours of retro gaming data from 660 players' sessions on the Nintendo Switch, the current flagship console of Japanese games company Nintendo. The device can play retro titles from six earlier-generation consoles, including the Nintendo Entertainment System from the 1980s.

By looking at the most-played retro games, the researchers found that the peak nostalgia period is childhood, at around 10 years old. They also discovered that the time gamers spent playing retro titles generally doubled between the ages of 20 and 40, when interest seemed to plateau (PsyArXiv, doi.org/pf3j).

The study's general findings look "approximately correct", but they could be skewed by the focus on Nintendo, says Bill Page at the University of South Australia. People included in the research are also limited to those with the money and motivation to buy the latest Nintendo console, as well as an additional subscription to access retro games, and such dedicated gamers may not be representative of all players.

In addition, video game players often buy older consoles and games later, when they are significantly cheaper, says Page. This means they may not have played the games that were released when they were children until much later, suggesting peak nostalgia actually occurs around late adolescence, he says. That would better match Page's research on music, which found that people prefer songs released during their adolescence and early adulthood. His research also suggests that people often enjoy older media despite having no nostalgia for it.

Nostalgia patterns will probably be different for other consoles and gamer populations, says Ballou. ▮

US science

US science faces existential crisis

The effects of the Trump administration's severe cuts to US scientific research funding could be felt for years, finds **Jeremy Hsu**

THE Trump administration has called for the US to revitalise its science and technology enterprise and accelerate research. But President Donald Trump has spent the past two months dismantling the very research apparatus built for this purpose.

It is an end to the "endless frontier", a vision set out after the second world war by technocrat Vannevar Bush, which posits that basic research is the driving force behind progress. It has persisted for 80 years, shaping the US into a leader in the sciences.

"The Trump administration is effectively banning many types of research it does not like"

Now, that vision has come crashing down. Thousands of jobs across federal agencies have been terminated and research funding worth billions of dollars has been suspended or cancelled.

The idea of the endless frontier spurred the formation of the US National Science Foundation in 1950 and led to expanded funding to other agencies, such as the National Institutes of Health (NIH). By 1961, science and technology funding hit $58 billion, even before the ambitious and costly moon missions began, and it continued going up, on average, until it reached a high point of $175 billion in 2009. It has dipped a bit, but remained around $158 billion in 2024, according to the US National Center for Science and Engineering Statistics.

And it paid off. The US landed on the moon, established weather and GPS satellites, created the modern internet and led the effort to complete the Human Genome Project. The economic payoffs for an investment this massive can be difficult to fully calculate, but they are considerable. A 2024 report by the non-profit organisation United for Medical Research found that every $1 of funding from the National Institutes of Health has delivered $2.56 in economic activity. The agency also says every $1 of publicly funded basic research stimulates an additional $8 of private investment in R&D.

SHAWN THEW/EPA-EFE/SHUTTERSTOCK

Carol Greider at the University of California, Santa Cruz, says that while federal research funding has gone up and down over the years, there is no comparison to what is happening now. Greider's 1984 discovery of the enzyme telomerase – which plays a crucial role in ageing and cancer processes – won her the 2009 Nobel prize for physiology or medicine. As someone whose research has been steadily funded by the NIH, she says the current moment is an "existential crisis" for her colleagues and students.

The future of US industry – such as technology, biotechnology and pharmaceutical companies – also hinges upon the students trained by research universities, she says. Multiple universities have already rescinded offers to PhD applicants and laid off staff in response to funding uncertainty, says Greider.

The clampdown on research spending has also had global consequences. For example, Johns Hopkins University in Maryland lost $800 million in grants from the United States Agency for International Development (USAID), which shut down research on preventing or treating tuberculosis, malaria and AIDS while eliminating more than 2200 jobs across 44 countries.

Cuts hit NASA

NASA has cancelled contracts and grants worth up to $420 million, following guidance from the Trump administration's Department of Government Efficiency (DOGE). The cuts will impact projects across the US. After DOGE announced the cuts, NASA confirmed the amount but refused to specify which programmes were cancelled.

Casey Dreier at The Planetary Society, a non-profit organisation based in California, compiled a list of programmes that recently lost funding using the agency's public grant database. NASA has since taken down the database and didn't respond to questions about the list's accuracy. Many of the cuts on Dreier's list align with President Donald Trump's scepticism towards climate science and his administration's targeting of its interpretation of diversity, equity and inclusion (DEI) programmes.

Climate-related cancellations on Dreier's list include a project at the Massachusetts Institute of Technology that uses satellites to map the impacts of extreme heat, air pollution and floods on prisons. Another target was University of Oklahoma research to develop digital twin simulations that predict the effects of floods on tribal lands.

Other research listed includes using bioengineered cells to see how space flight affects the human body. *New Scientist* contacted those that appear to have been affected, but most did not respond.

A NASA spokesperson told *New Scientist* that the agency is "optimising its workforce and resources in alignment with the Department of Government Efficiency's initiatives".

Cancellations of ongoing grants and contracts fly in the face of the "rigorous" review process that selected them, says Michael Battalio at Yale University. "Politics cannot and should not define what is scientifically worth studying at the level of individual grants."

President Trump has signed many executive orders since inauguration

Projects both within and outside the US have also been scrutinised for alignment with the Trump administration's climate scepticism and hostility towards diversity, equity and inclusion. "The Trump administration is not just cutting funding across the board, but also effectively banning many types of research it does not like," says Yangyang Cheng at Yale Law School. That could shape the trajectory of scientific inquiry and technological development around the world, she says.

Brain drain

Opportunities outside the US now beckon researchers, says Danielle Beckman, a Brazilian-born neuroscientist at the California National Primate Research Center. She says her lab had multiple federal grants that were either cancelled or trapped in suspended review – and she has encountered university hiring freezes while applying for other positions. Now she is preparing to go to Germany.

Scientists have always faced a choice of where to do their work, but the incentives for choosing the US are evaporating. Wolfgang Ketterle, who won the Nobel prize in physics in 2001, says he faced a choice in 1998 between staying at the Massachusetts Institute of Technology or accepting an offer for work in Germany. He stayed at MIT – but said he would have gone home if faced with the uncertainty hanging over US researchers today.

"Science needs continuity and reliable planning," says Ketterle. "This is in danger now, and we will soon see the consequences that the US is no longer the place for the best scientists to be." ▮

Comment

Anti-vaccine sentiment is now embedded in US government

The erosion of trust in vaccines during a measles outbreak is a dangerous national experiment, says **Chelsea Whyte**

THIS is a precarious moment for public health in the US. On 1 April, Robert F. Kennedy Jr, who heads the US Department of Health and Human Services (HHS), began overseeing sweeping layoffs of an estimated 10,000 people at the agency. The cuts aren't just wide but deep – they jeopardise studies that have been running for decades and threaten labs that are key to fighting polio and influenza within the US and around the world.

Dozens of senior leaders of HHS agencies, including the National Institutes of Health, the Centers for Disease Control and Prevention and the Food and Drug Administration (FDA), have been placed on leave or offered reassignment to other agencies. These departures leave the nation's public health apparatus in chaos and headed by a longtime vaccine sceptic.

Peter Marks resigned as head of the FDA shortly before the layoffs, citing Kennedy's "misinformation and lies" in his 28 March resignation letter. "Undermining confidence in well-established vaccines that have met the high standards for quality, safety, and effectiveness that have been in place for decades at FDA is irresponsible, detrimental to public health, and a clear danger to our nation's health, safety, and security," he wrote.

It is a hazardous time to lose leaders dedicated to the science behind vaccines. National vaccination rates declined during the covid-19 pandemic and haven't bounced back. Rates of routine childhood vaccines that are normally required to enter kindergarten – including measles, mumps and rubella (MMR); diphtheria, tetanus and pertussis (DTaP); polio; and varicella – have dropped to 93 per cent of incoming students on average. Idaho has reported the lowest MMR vaccination rate of 81.3 per cent. To reach herd immunity, public health officials aim for 95 per cent, and the US is now in the midst of a measles outbreak.

> **"This is a hazardous time to lose leaders dedicated to the science behind vaccines"**

And yet, under Kennedy's leadership, HHS is undertaking a study into the widely debunked claim that there is a connection between vaccination and autism, led by long-standing vaccine critic David Geier.

To be clear, no rigorous studies have found such a link. This fear can be traced back to a single study led by Andrew Wakefield that was published 27 years ago in the prestigious scientific journal *The Lancet*, which looked at 12 children and implied their autism was linked to having had the MMR vaccine. Twelve years after it was published, *The Lancet* retracted the study, on the grounds that the findings were incorrect.

The retraction was far too late to extinguish the anti-vaccine scare it had sparked. A generation later, the US is haunted by the study's legacy. The US anti-vaccine movement has gained so much momentum that it is now firmly embedded within the highest levels of government.

When contacted for comment, a spokesperson for HHS responded that "this overhaul is about realigning HHS with its core mission: to stop the chronic disease epidemic and Make America Healthy Again".

But the truth is that Kennedy's decimation of the public health agencies and erosion of trust in vaccines is unleashing a dangerous national experiment. It is the stuff of nightmares for the millions of researchers and public health workers who have, for decades, used the instruments of science to render many of humanity's worst illnesses – once widespread causes of childhood mortality – a distant memory. ▮

A protester at the Stand Up For Science rally in New York City on 7 March

NIGRO/PACIFIC PRESS/SHUTTERSTOCK

Chelsea Whyte is *New Scientist*'s US Editor

Botany

Plant skin grafts could result in new kinds of pest-resistant vegetables

Michael Le Page

A NEW technique for creating fruits and vegetables with the skin of one variety and the flesh of another could make crops more resistant to pests and drought.

A lot of the fruits and vegetables we eat come from grafted plants created by cutting off part of one plant and replacing it with part of another. What makes grafting useful is that even plants that are too distantly related to hybridise can be grafted together. For instance, a desirable variety of fruit plant can be grafted onto a rootstock of another type that is resistant to pests and diseases.

Very occasionally, a shoot arises from the junction between grafted plants with the outer layer of one plant and the insides of another – called a graft chimera. This can happen because shoots develop from three distinct layers of stem cells at their tip, one of which forms the skin of the plant. By chance, shoots from a graft junction can end up with a mix of stem cell types from the two plants.

KEYGENE

The graft chimera potato (centre) mixes Pimpernel (left) and Bintje (right)

Normally, creating a certain type of grafted plant requires performing a graft for each one you want to cultivate, so making large quantities is taxing. But graft chimeras can be propagated by taking cuttings from them or simply from their tubers, which would make them more desirable.

However, while researchers have occasionally deliberately created graft chimeras, many are a very rare accidental byproduct of conventional grafting.

Now, Jeroen Stuurman at KeyGene, a crop technology company in the Netherlands, says he has developed a reliable way to produce graft chimeras for the first time. He won't reveal details of the method, but he says he has used it to create many different types from varieties of potatoes, tomatoes and aubergines, and between sweet and chilli peppers.

For one graft-chimera potato, with the skin of a variety called Pimpernel and the flesh of another called Bintje, KeyGene has been awarded plant breeders' rights – the horticultural equivalent of copyright. This is a first for a graft chimera. Getting these rights shows it is a potentially viable business, says Stuurman.

The company is now planning to create graft chimeras that are resistant to pests and diseases. Pest resistance is often due to hair-like structures called trichomes on the surface of plants, which may secrete repellents or sticky substances to trap insects, says Stuurman. Trichomes are very hard to transfer between plant varieties with conventional breeding or genetic engineering as they involve many genes, but his method allows existing varieties to be effectively given a "skin transplant". Because potatoes are already grown from tubers rather than seeds, farmers could start growing such graft chimeras tomorrow, says Stuurman.

"For one graft hybrid potato, KeyGene has been awarded the horticultural equivalent of copyright"

"It's really interesting that they can make stable graft chimeras that have commercially relevant properties," says Charles Melnyk at the Swedish University of Agricultural Sciences. "I'm not aware of this being done before, so their finding is really significant." ▮

Health

Weekend workouts may be as good as daily exercise

YOU don't need to exercise every day to be healthy. "Weekend warriors" who squeeze in at least 150 minutes of moderate to vigorous activity over just one or two days seem to have similar health benefits as those who are consistently active all week.

The World Health Organization recommends that most adults do at least 150 minutes of moderate-intensity physical activity each week, which includes brisk walking, or at least 75 minutes of vigorous activity, such as running, or a combination of both.

To investigate whether it makes a difference when people exercise, Zhi-Hao Li at Southern Medical University in Guangzhou, China, and his colleagues analysed data in the UK Biobank study on the physical activity of more than 93,000 people, aged between 37 and 73. This was recorded by wrist accelerometers, worn between 2013 and 2015.

Over eight years of follow-up, nearly 4000 of the participants died. The researchers found that among people who did at least 150 minutes of weekly physical activity but squashed it into one or two days, the risk of death from all causes, cardiovascular disease and cancer was 32 per cent, 31 per cent and 21 per cent lower, respectively, than it was for less active people.

SOLSTOCK/GETTY IMAGES

Many people enjoy going for a run in the park on the weekend

For those who spread their activity throughout the week, the risk of death from all causes, cardiovascular disease and cancer was 26 per cent, 24 per cent and 13 per cent lower, respectively, than it was for the less active people (*Journal of the American Heart Association*, doi.org/pfwn). This might make it seem that exercising at the weekend is better than spreading out your physical activity, but there was no statistically significant difference.

"This study adds to what we know about the 'right' way to be active. That is, there is no single 'right' way," says I-Min Lee at Harvard Medical School. ▮

Chris Simms

Do Ozempic and Wegovy really cause hair loss?

Some people experience hair loss when taking weight-loss drugs, but is it down to the drugs or other factors, asks **Grace Wade**

THE use of weight-loss drugs like Ozempic and Wegovy has skyrocketed in the Western world. But as more people turn to these treatments, which mimic the appetite-suppressing hormone GLP-1, more potential side effects are emerging, including hair loss.

Evidence of this first appeared during clinical trials of Wegovy. Of the more than 2100 adult participants taking the drug, 3 per cent experienced hair loss, compared with only 1 per cent of the roughly 1200 participants taking a placebo. A similar effect was seen in children and teenagers aged 12 to 17 years old: among the 133 of them who were taking the drug, 4 per cent developed hair loss, whereas none of the 67 in the placebo group did.

To learn more, Mohit Sodhi at the University of British Columbia in Canada and his colleagues looked at a larger group of people. They used electronic records to collect health data spanning from 2006 to 2020 on more than 3200 adults in the US, of whom 1926 were prescribed semaglutide – the GLP-1 drug in Ozempic and Wegovy – and 1348 were given an obesity medication called bupropion-naltrexone.

None of the participants had diabetes, which suggests that those using semaglutide, which can be prescribed for obesity or type 2 diabetes, were taking it for weight loss, says Sodhi. The researchers tracked which participants were later diagnosed with any form of hair loss for the first time.

After accounting for variables such as age, sex, location and any underlying health conditions, they found that those prescribed semaglutide were 52 per cent more likely, on average, to develop hair loss than those taking bupropion-naltrexone.

REBECKA UHLIN/BILDHUSET/PLAINPICTURE

Women may be more likely than men to lose hair when taking weight-loss drugs

However, when stratifying the results to compare men against women, the team found that women were almost exclusively driving the association. Overall, the 1026 women taking semaglutide were more than twice as likely to experience hair loss as the 1097 women using bupropion-naltrexone. Only one man was newly diagnosed with hair loss in each treatment group, out of the 1151 men in the study.

Side effect or sideshow?

This might reflect a genuine difference between men and women, but it is also possible that there were too few men to capture an association, says Sodhi. Alternatively, men are more likely to experience balding and hair loss than women, so may be less likely to seek a diagnosis for it, he says.

It also isn't clear whether semaglutide or another factor is responsible for participants' hair loss. "There are so many things that can affect hair," says Priya Jaisinghani at New York University's Langone Health medical centre. These include stress and sleep quality, which weren't accounted for in the analysis, she says.

Sleep disturbances and stress are also associated with weight gain, and seeing that semaglutide appears to more effectively treat obesity than bupropion-naltrexone, it may be more likely to be prescribed for severe obesity. This could create the illusion that semaglutide has hair loss as a side effect, when it may actually be lifestyle factors driving both hair loss and severe obesity.

Another possibility is that semaglutide may trigger a form of hair loss called telogen effluvium. This occurs when a stressor, such as rapid weight loss, disrupts the hair growth cycle, causing active hair follicles to stop growing. Usually, growth resumes once the stressor has passed. Any intervention that produces rapid weight loss, such as bariatric surgery or extreme calorie restriction, can lead to telogen effluvium, says Jaisinghani. This could explain why semaglutide is associated with a greater risk of hair loss compared with less effective weight-loss drugs, says Sodhi.

In addition, while both semaglutide and bupropion-naltrexone work by suppressing appetite, the former appears to do this more effectively. This could heighten the risk of nutrient deficiencies, says Sodhi. "If someone is not getting enough nutrients, whether that is from extreme calorie cutting or not getting enough protein or following an unbalanced diet, they could experience side effects or a reaction such as hair loss," says Jaisinghani. "This is why it is really important to discuss safe and sustainable rates of weight loss with your doctor, and that is along with ensuring adequate protein intake and a well-balanced, nutrient-forward diet," she says.

While more research is needed to determine whether semaglutide directly contributes to hair loss, the studies to date add to our growing understanding of the potential side effects of drugs like Ozempic and Wegovy, which will help people and their doctors make informed choices around their use, says Sodhi.

52%

How much more likely, on average, those on semaglutide were to develop hair loss compared with those on another obesity drug

"Semaglutide's efficacy and safety have been extensively demonstrated in people with obesity/overweight with robust evidence for improving health outcomes," says a spokesperson for Novo Nordisk, the maker of semaglutide. "Novo Nordisk remains confident in the benefit-risk profile of our GLP-1 medicines, when used consistent[ly] with their indications and product labelling." ▮

Agriculture

Aged human urine could protect threatened crops

Matthew Sparkes

HUMAN urine that has been matured in the sun for at least one month appears to be both a fertiliser and an effective pesticide. The findings could help combat insect infestations in West Africa, where soil quality is typically low and traditional pesticides are expensive.

Farmers taking part in a previous trial in Niger to investigate the use of urine as a fertiliser discovered that plants treated with it had less pest damage than those that weren't. Laouali Amadou at the National Institute of Agricultural Research in Niger and his colleagues decided to test the findings on cowpeas (*Vigna unguiculata*), a vital crop in the country because of its drought tolerance.

Experiments were carried out in several villages across Niger to compare the effects of chemical pesticides and human urine on the crop's pest resistance. Three applications were made at each site, with a week between treatments.

The team found that plots treated with synthetic pesticides had the lowest amount of insect damage. But those treated with human urine had 20.5 times less infestation than control areas; their crop yields were also 1.8 times higher (*American Journal of Plant Sciences*, doi.org/pfvh).

The urine was housed in large containers and fermented in the sun for one or two months to kill any pathogens. "The odour is very, very strong," says Amadou. He says it isn't yet clear exactly what causes the pesticide effect, but the smell is one possibility.

Team member Ibrahim Boukari Baoua at the Dan Dicko Dankoulodo University of Maradi in Niger says the smell has no impact on the cowpeas' taste. He says the approach could be a lifeline for farmers: "Soil fertility is very low in West Africa. And chemical fertilisers are very, very expensive." ▮

Zoology

Bonobo communication has a similar structure to our own

Sophie Berdugo

BONOBOS combine their calls in a complex way to form distinct phrases, a sign that this type of syntax is more evolutionarily ancient than previously thought.

One core block of human language is syntax, where meaningful units are combined into longer sequences, like words into sentences. This is due to compositionality, where the meaning of the whole comes from the meaning of the parts.

This isn't unique to humans. Chimpanzees, for example, combine calls to warn others of snakes. But, so far, only "trivial compositionality" has been identified in non-human animals, whereby each unit adds independently to the meaning of the whole. For example, the phrase "blonde dancer" has two independent units: a blonde person who is also a dancer. Humans were thought to be unique in having "non-trivial compositionality", where the words together mean something else than what they mean individually. For example, "bad dancer" doesn't mean a bad person who also dances.

To investigate further, Mélissa Berthet at the University of Zurich in Switzerland and her colleagues spent five months following 30 adult bonobos in the Kokolopori Bonobo Reserve in the Democratic Republic of the Congo, recording almost 1000 instances when a bonobo called out. Of these utterances, roughly half were combinations where at least two different call types were paired together in quick succession.

"This type of syntax is more evolutionarily ancient than previously thought"

In a new step, they noted everything that was happening at the time of the call and in the minutes after. They recorded over 300 of these observations, including the behaviour of the caller and audience afterwards.

To reveal the meaning of each call, they created a cloud of utterance types, placing calls that occurred in similar circumstances closer together. "We kind of established this dictionary," says Berthet. "We have one vocalisation and one meaning."

Once they had done this, they could see whether the individual calls in combination had distinct meanings. They identified four compositional calls, of which three were clearly non-trivial (*Science*, doi.org/pf2x).

For example, "high-hoot + low-hoot" combines the calls that seem to mean "pay attention to me" and "I am excited" to say "pay attention to me because I am in distress", which bonobos often use to call for support when another individual is intimidating them.

"It's the first time in any animal species that there is an unambiguous evidence for non-trivial syntax, non-trivial compositionality, and so that changes the game," says Maël Leroux at the University of Rennes in France. "It's revolutionary."

This finding doesn't mean that bonobos have language, because language is the human communication system, says Berthet. "But we're showing that they have a very complex communication system that shares parallels with human language."

Now that we have evidence that both chimps and bonobos have syntax, it is inevitable that the capacity for compositionality came from our last common ancestor, says Leroux. "They just showed, unambiguously, that this core building block is evolutionary ancient and at least 7 million years old, and maybe even older." ▮

A bonobo mother calls out to other group members

LUKAS BIERHOFF, KOKOLOPORI BONOBO RESEARCH PROJECT

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Views

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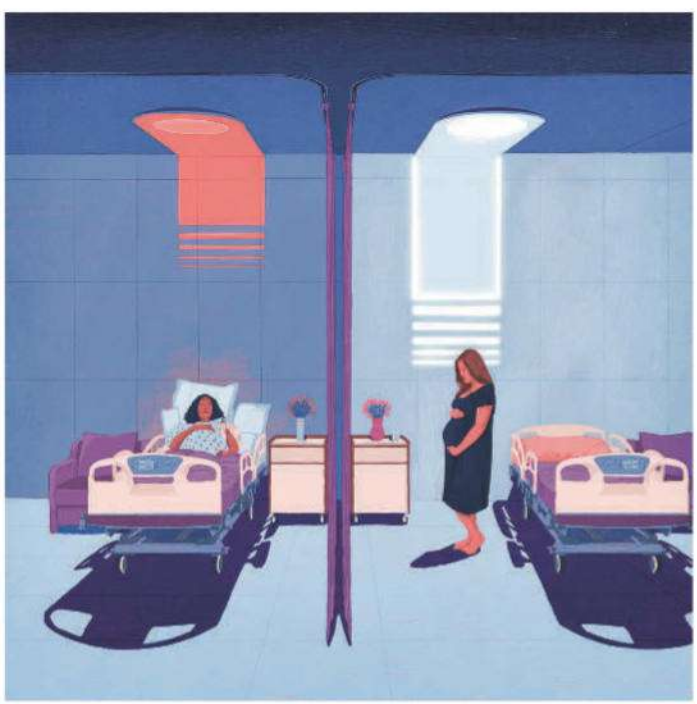
Comment

Just a little lie-down

Bed rest is commonly prescribed for high-risk pregnancies. It can't hurt and might help, right? Wrong, says **Jacqueline Sears**



SIMONE ROTELLA

I WAS on bed rest for five weeks during my third pregnancy. I did everything I was supposed to. Even though it felt impossible to parent my 4 and 5-year-old boys from the couch, it became even more challenging when I was admitted to bed rest in hospital. Who wants to do the wrong thing and risk endangering their future baby? Bed rest in some pregnancies is so normalised that there is a widespread belief it must be good for something or doctors wouldn't prescribe it. Right?

Wrong. In the US, the Society for Maternal-Fetal Medicine published the first formal guidance against bed rest in 2014, which was endorsed by the American College of Obstetricians and Gynecologists. Trying to be an informed patient, I read published studies that didn't support what I was being asked to do. But my doctor insisted. Activity restriction has long been viewed by doctors as a "can't hurt, might help" approach. It remains one of the most commonly prescribed interventions to prevent premature birth and treat the conditions that can lead to premature labour, impacting roughly 20 per cent of women with high-risk pregnancies around the world every year.

But data is overturning this age-old practice and doctors need to catch up. No high-quality studies have shown that bed rest helps fetuses gestate longer or have better health outcomes. What's more, many studies since the 1950s have documented that bed rest can pose considerable harm to those who are pregnant and their families. While "taking it easy" or staying in bed may appear innocent, bed rest demands levels of inactivity that can rapidly reduce heart and lung function, initiate muscle and bone loss, and increase the risk of gestational diabetes, blood clots and deadly pulmonary embolisms. It also isolates women from their communities, increases the risk of anxiety and depression, causes family stress and leads to job instability and lost wages.

Despite this, a 2009 paper in the *American Journal of Obstetrics and Gynecology* reported that most maternal-fetal medicine specialists would recommend bed rest for some conditions "even though the majority believed bed rest was associated with minimal or no benefit". A 2022 study found that 1 in 3 women considered at high risk of preterm birth were placed on activity restriction by their doctor even though the hospital had a policy against it.

When I transferred hospitals and switched providers, I learned there was a different approach. My new doctor said bed rest wasn't an evidence-based intervention and liberated me. My pregnancy was complicated, so I still had to stay in the hospital, but at least I could freely shower, go to the bathroom and move throughout the day.

Even though the data doesn't indicate that restricting activity prevents preterm birth, patients listen to their doctors. The 2022 study underscored a compliance rate of 100 per cent as "a strong reminder of the impact prescribing patterns of physicians can have on patients". We know research takes a long time to make its way into everyday medical practice, on average 17 years. We also know that pregnant people and their families can't wait – they need evidence-based support right now. There is no evidence to suggest that mothers-to-be can safeguard the health of their future babies through bed rest.

After my experience, I worked with other parents of babies in neonatal intensive care units, as well as doulas, as an advocate and support group facilitator. Even the most informed parents worry about pushing back when their doctor recommends bed rest. Doctors need to do a better job of listening to the data and their patients' legitimate concerns. And, if need be, parents-to-be should be willing to find a new provider who respects the evidence. ▮

Jacqueline Sears is a science writer based in Richmond, Virginia

Future Chronicles

One giant leap

Our guide to the future **Rowan Hooper** reveals how even a trip to Mars became possible after a brain-computer interface allowed us to fully inhabit robot avatars in the late 2020s

Rowan Hooper is *New Scientist*'s podcast editor and the author of *How to Spend a Trillion Dollars: The 10 global problems we can actually fix*. Follow him on Bluesky @rowhoop.bsky.social

In Future Chronicles, he explores an imagined history of inventions and developments yet to come.

This column appears monthly. Up next week: Chanda Prescod-Weinstein

IN 2034, the first person landed on Mars. While she didn't go there physically, she still experienced the planet intimately. She explored an ancient river delta and built a base. She put up a flag (China's) and conducted a detailed analysis of rock samples. She achieved all this by inhabiting a robot via a sophisticated brain-computer interface. Some people claimed the woman had – in a real sense – been to Mars.

Critics said she hadn't, because her body was always in a lab in Beijing. Ah, but her *mind* was on Mars, replied her supporters. That there was even an argument demonstrates how far brain-computer interfaces (BCIs) had improved. And, as with many advances, artificial intelligence proved the key.

The basic idea of a BCI is to pick up the signals of a living brain and enmesh them with the electronics of a computer. It is easier said than done. Brain activity is messy, coming from multiple locations and having overlapping and interfering properties and imprecise meanings. But improvements in neuroengineering and machine learning able to interpret the signal made it possible to record complex brain activity from electrodes planted into a subject's cortex, and translate it into a range of actions.

The technology was initially driven by surgeons hoping to improve the quality of life for people with paralysis or locked-in syndrome. The first BCI using electrodes was implanted in a paralysed man in 1998, consisting of just two electrodes. The man became able to spell out words on a computer by moving the cursor with his mind. Such breakthroughs were world-changing for people who were otherwise unable to communicate.

The problem was that electrodes were few, while neurons numbered in the billions. Improvements in micro-electrode construction allowed neuroscientists to record more brain activity; in 2014, Juliano Pinto, a paraplegic unable to move his legs, inhabited an exoskeleton and, using mind control, kicked the first ball at the FIFA World Cup in Brazil.

In 2023, a Swiss team used an "electrocorticography" array placed on the brain – but without penetrating it – to pick up signals from a paralysed man's motor cortex and relay them to the spinal cord. An interface at the spinal cord then sent the signals to the man's legs, allowing him to walk again. A similar interface allowed a woman unable to speak after a stroke to "inhabit" a digital avatar and speak through it. By 2025, a paralysed man was able to pilot a drone; eventually people could "inhabit" such drones.

> **"Consciousness had relocated to the robot's body – the human felt that they had become the avatar"**

By the end of the 2020s, paralysed people could inhabit exoskeletons and robots by sending their thoughts to the machine, just as people had done to control cursors on a screen. The difference was that signals also went the other way: from machine to human. The human controller's senses were fed directly from the robot's cameras and microphones, and haptic feedback – the transmission of touch using vibration and pressure suits – helped give the user a "real" sense of location. Retinal and cochlear implant technology had progressed enough that scientists could override the direct input into someone's eyes and ears, and replace them with inputs from a remote feed. Similar inputs enabled smell and taste.

The upshot of all this: people could operate a robot remotely and see, hear and feel things that it interacted with. They were able to explore and experience extreme environments – the crushing depths of the ocean, the caldera of an active volcano. The boundary between self and machine softened, especially when the robot could interpret emotional cues, building on work by Ali Zia at the Australian National University in Canberra.

Robots would move faster if the human controller was happy and excited, and more cautiously if the person was nervous. A facial display on the robot would indicate a feeling such as happiness or confusion, and then a human could understand what the robot was "feeling". The user's consciousness relocated from their body to the robot's; the human felt they had become the avatar, hence the argument that the telepresent robot really did represent the first human on Mars.

Such was the success of these space missions that it was years before state-owned space agencies committed to the risk and expense of sending humans. Even greater success came with rescue robots, as they were called, which were used as avatars to enter burning buildings or war zones and evacuate people. The rescue robots name, however, came to refer to the escape that paralysed and locked-in people were able to achieve from their beds. ▮

New Scientist Events

Subscriber event

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Online, 10 June 2025 | 6-7pm BST / 1-2pm EDT

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LIVE LECTURE + Q&A

Delilah Gates, Postdoctoral fellow, Harvard University

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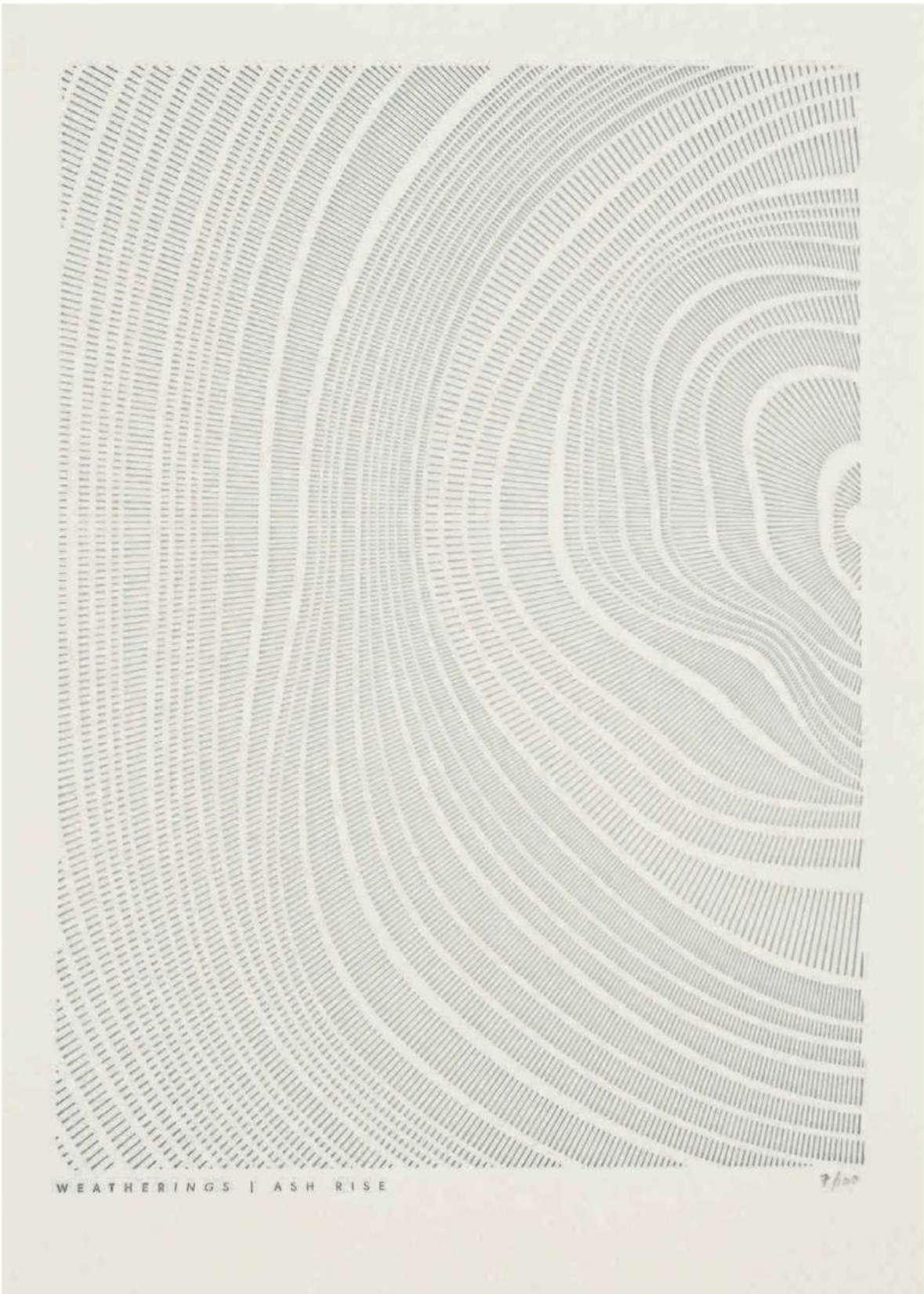
WEATHERINGS | ASH RISE

Left: Using data from the UK's Meteorological Office, each growth ring represents a year, the thin lines represent daily rainfall and gaps between lines indicate daily temperatures.

Above: The barbs on the right represent the population of 100 UK bird species 40 years ago. The left shows present-day population sizes.

Pattern play

Rebecca Kaye

REBECCA KAYE, also known by her alias Ploterre, turns idle thoughts that arise while cycling into beautiful prints with a helping of hard data and clever design.

The Edinburgh, UK, resident studied mathematics and worked as a data researcher, developing her art as a sideline. Then covid-19 hit, and she leapt into art full-time.

Her work inevitably begins outside in nature and arrives as a curious thought: how do tide times change around the coast, where do oxeye daisies grow across the UK, or how do the unique flashing patterns of lighthouses differ?

"Normally, I suppose, you'd walk past something and wonder why that leaf pattern looks the way it does, and most people would just carry on walking and forget about it," says Kaye. "I've turned it into a bit of a job."

Once she has an idea, the hunt for data begins. A recent question that popped into Kaye's head was whether it was always raining at least somewhere in the UK, which led her to review 130 years of records that led to the perhaps unsurprising and gloomy discovery that, yes, it usually is.

Once a visual design has been sketched out on paper, Kaye then turns to a computer to sculpt formulas that contort the data into her design, merging information and form into a single piece that tells a story. This eventually leads to a finished design that is screenprinted by hand.

Matthew Sparkes

The race to crack cuneiform

The world's oldest script defied deciphering – until 1857. What happened next makes a terrific and gripping read, finds **Michael Marshall**

Book

The Mesopotamian Riddle

Joshua Hammer

Simon & Schuster

THE TRUSTEES OF THE BRITISH MUSEUM

A close-up shot of the cuneiform script on an ancient column (below)

WHAT does it take to decipher an extinct writing system? If Joshua Hammer's new book *The Mesopotamian Riddle: An archaeologist, a soldier, a clergyman, and the race to decipher the world's oldest writing* is anything to go by, the main requirements are some ethically dubious archaeological digs and a lot of rampaging testosterone.

The book is Hammer's account of the deciphering of cuneiform, the oldest known writing system. Cuneiform was invented in around 3400 BC in Mesopotamia. It was used for thousands of years to record the triumphs and failures of a succession of societies, before finally falling out of use around 2000 years ago.

In the 1800s, archaeologists rediscovered cuneiform, as artefacts were excavated in what was once Mesopotamia and shipped to Europe – often against the will of local communities. People wanted to know what the strange wedge-shaped symbols meant. Egyptian hieroglyphs had been deciphered in the 1820s: how hard could it be to read cuneiform?

Quite hard, it turns out. Because the writing system was used for so long, multiple languages were recorded using the same set of symbols. Worse, some of the symbols had multiple uses: the same image could denote a sound or a concept, depending on the context – and, of course, the context was frequently missing.

Despite, or perhaps because of, the challenges, three men set their sights on deciphering cuneiform. Austen Henry Layard was a failed lawyer turned reckless adventurer turned archaeologist. Henry Creswicke Rawlinson was a soldier with a passion for linguistics and an appalling snob. And then there was Edward Hincks, a parson and part-time scholar in rural Ireland.

Hammer starts the story at the most dramatic point: in January 1857, the Royal Asiatic Society of Great Britain and Ireland launched a competition to decipher the cuneiform on a newly discovered artefact: an octagonal column, known as a prism, which was inscribed with 800 lines of tiny cuneiform characters. The idea was to see if multiple experts arrived at the same translation, because sceptics argued that other translations were so riddled with unfalsifiable assumptions that they were little better than guesswork. Spoiler alert: the translations were sufficiently similar that it was clear there was an objectively right path to be on, even if some of the details were hazy.

From there, Hammer delves into each man's personal history and tracks his work, until the story comes full circle. His writing is engaging, moving nimbly between the men's foibles, the geopolitics and the cuneiform puzzle itself. His explanations of the art of deciphering are terrific, conveying both the difficulty and how the researchers overcame it.

The book has its flaws. One issue is that there are so many strands: three protagonists, two of whom criss-cross Eurasia; multiple archaeological sites, representing ancient civilisations like Assyria, Sumer and Persia; a host of languages all recorded in cuneiform. There were passages where I found myself losing track. Hammer supplies a useful timeline of ancient Mesopotamia, but one for his protagonists would have helped. Readers might do well to prepare with Moudhy Al-Rashid's *Between Two Rivers*, which recounts the history of Mesopotamia.

And then there are the maps, which are diabolical. The main one uses a greyscale key to identify different populations, but the shades are so similar that it is almost impossible to differentiate between them. A second map, of the Achaemenid Empire, uses such a confusing greyscale I found it hard to tell land from sea. This was also inserted, a bit randomly, into chapter two. Publishers, please place all maps in the opening pages for easier reference.

These niggles aside, *The Mesopotamian Riddle* is a gripping account of a crucial project in archaeology and linguistics. It exposes the flawed humanity of its protagonists, while showing the scale of their achievements. ▮

Michael Marshall is a writer based in Devon, UK

Getting political on cancer

A much-needed book with a political take on cancer is dense and deep. But do stay with it, says **Karmela Padavic-Callaghan**

Book

Metastasis

Nafis Hasan

Common Notions

IN 2000, then-US president Bill Clinton said: "It is now conceivable that our children's children will know the term cancer only as a constellation of stars." A quarter of a century later, cancer is far from banished to the celestial realm. In fact, cancer deaths are predicted to nearly double globally by 2050, and cases are rising in the under-50s across many different tumour types.

Clinton made his prediction at an event celebrating the mapping of the human genome. This promised to add new tools to researchers' cancer arsenal, and did so in the shadow of the "war on cancer", launched by Richard Nixon 30 years earlier. What went wrong?

In *Metastasis: The rise of the cancer-industrial complex and the horizons of care*, Nafis Hasan offers an answer in the form of a sharp critique of how cancer research and cancer care interact with the money-making systems of drug development, health insurance and more. The problem with curing cancer, he argues, isn't just an issue of unanswered scientific questions, but also of the political and economic forces that shape how we ask them, and which answers are deemed most legitimate.

It may not come as a shock to many that cancer treatments are expensive and that drug manufacturers care about their profit margins, but Hasan is well-placed to take the argument deeper, as he spends his working life between the healthcare sector, where he is a labour organiser, and research at the Brooklyn Institute for Social Research in New York.

He systematically presents the history of cancer research and discusses how we learned that cancer is caused by gene mutations, though focusing on that alone hasn't always led to the most effective treatments. He links this both to market forces behind the scientific tools used in this research and to the philosophical inclinations of mainstream research institutions.

Hasan also underlines the rift between efforts to prevent cancer and to cure it, labelling the increasing emphasis on "selling" cures as decidedly political compared with following the science by, say, more strictly regulating chemicals people are exposed to. In this sense, *Metastasis* is a political book. Hasan sees capitalism, and the way science and medicine are done within it, as a key factor in the state of cancer research and the prevalence of the disease.

For instance, he discusses the labour conditions of researchers and how their wages and the pressure to produce something marketable influence the research process. And while some of the language in *Metastasis* may strike more conservative readers as radical, the facts Hasan presents – US government trials where only a few of the drugs produced any response in tumours, and the vast number of cancer drugs that don't extend patients' lives – are alarming enough to call for radical solutions.

***Metastasis* isn't an easy read. It is dense with biology and political theory, which can make it less than accessible. An extra chapter on the basics of molecular biology would have helped, and at times the book's tone and style felt better suited for a dissertation than popular science. But in the few instances where Hasan engages personally with readers, sharing his experience with cancer, the book benefits greatly from the reminder that it is you, me and our loved ones who are hurt by the socioeconomic forces it reveals.**

Its style and density make *Metastasis* an imperfect book and its engagement with Marxist philosophy isn't mainstream in US science writing. But it is also deeply necessary and illuminating. Most importantly, Hasan isn't writing from a place of despair – the book ends with a call to imagine new horizons of care and start organising to reach them, even if they seem as distant as the stars.

The war on cancer continues, with new tech such as this AILIS breast-screening machine

KLAUDIA RADECKA/NURPHOTO VIA GETTY IMAGES

New Scientist *recommends*

Alison Flood
Culture editor
London

When your children range from 8 to 14 years old, it's hard to find a weekend film for the whole family, particularly with a grandad in the mix as well. Happily, the 2015 film

adaptation of Andy Weir's **The Martian**, starring Matt Damon (pictured) as Mark Watney, an astronaut who is accidentally abandoned on Mars, fitted the bill.

There's something wonderfully enjoyable about watching people being very clever. From Mark's brilliance growing his potato crop in Mars's sterile soil to NASA 's ingenious idea for the slingshot manoeuvre to get him home, we lapped it up.

The only low point came when Mark said he was going to have to "science the shit out of this" to stay alive. And not because my 8-year-old heard the s-word (he's watched *The Traitors*, after all). My husband (an engineer) felt the right word should have been engineer, not science. Regardless: what a great line it is – and what a joy of a movie.

ATLASPIX/ALAMY

The classics column

A world to rethink As *New Scientist*'s book club picks *Ringworld*, Larry Niven's science fiction classic, for its April outing, **Emily H. Wilson** revisits the 55-year-old novel to find out how it has stood the test of time

Emily H. Wilson is a former editor of *New Scientist* and the author of the *Sumerians* trilogy, set in ancient Mesopotamia. The final novel in the series, *Ninshubar*, is out in August. You can find her at emilyhwilson.com, or follow her on X @emilyhwilson and Instagram @emilyhwilson1

Book
Ringworld
Larry Niven
Gollancz

Emily also recommends...

Book
The Draco Tavern
Larry Niven
Tor Publishing
Strictly speaking, this section should be entitled "Larry Niven also recommends". I exchanged emails with him recently in order to plan an interview, and I asked him which one of his books he would particularly recommend to me. He immediately replied with The Draco Tavern. *I haven't had time to read it yet, but I am very happy to pass on this recommendation from the man himself.*

Over the years, *Ringworld* has been imagined by many artists

RINGWORLD by Larry Niven was published in 1970 to huge acclaim, winning both Hugo and Nebula awards; it's been in print ever since.

It came out when humans had just landed on the moon and it looked like we might be on our way to the stars. The title alone evokes a particular golden age of science fiction, when (mostly male) writers wrestled with big physics and big ideas, imagining far-off futures where humans had galactic-scale adventures.

Authors like Niven wanted to imagine what might be out there in the universe, and they took pride in trying to get the science right. With *Ringworld* featuring in the *New Scientist* book club this month, it seemed like a good time to revisit the novel, having last read it as a teenager.

How did this 55-year-old work stand the test of time? After all, many books from this era have dated badly. Sometimes it is because science has now rendered their plotlines silly; sometimes it is because the sexual politics (or other cultural aspects) have begun to stink over the decades.

Well, to start with, this book is stuffed full of ideas! You can see why it was a smash hit and ended up being part of a sprawling network of follow-up stories, prequels and spin-offs.

Given how much internal lore is thrown at us, I found the novel surprisingly zippy and exposition-light. Our 200-year-old hero Louis

"*Ringworld* evokes a golden age of sci-fi when writers (mostly men) wrestled with big physics and big ideas"

Gridley Wu, a human and seasoned adventurer, is approached by Nessus, an alien known as a puppeteer, and asked to come on a mysterious mission in exchange for access to new technology.

Wu and Nessus are to be joined on their adventure by a feline, warlike "kzinti" alien called Speaker-to-Animals (the animals in question being other species), and a young human woman named Teela Brown, whose qualities become evident only later in the story. This gang travels to the eponymous Ringworld and, after being fired on by an ancient security system, crash-lands on it.

The Ringworld is the star of this show. It is an ancient artefact of almost unimaginable scale: a ribbon world, looped around a star, 1.6 million kilometres wide and with an inner surface area the size of 3 million Earths. With a diameter of 305 million kilometres, it is fashioned from a substance with amazing tensile strength. On the terraformed inner surface of the Ringworld, a civilisation has fallen, but life goes on.

Wu and the gang must travel a vast distance across the inside of the ring to look for a way to leave it; along the way, as you might expect, they have plenty of adventures.

As for the mores of this 1970 novel, there are things a modern editor would probably want to cut, and they might well want the female characters to be given more depth.

The science, meanwhile, was thoroughly picked apart by readers at the time, so much so that Niven's follow-up, *Ringworld Engineers*, published a decade later, was basically a riposte to all those who had nitpicked the mechanics of Ringworld.

This isn't my favourite Niven; that is *A World Out of Time*. However, revisiting *Ringworld* has made me hungry to plunge back into his universe. I plan to reread some of his other classics, like *The Mote in God's Eye*, as well as *Ringworld*'s follow-ups, because there are so many interesting questions that go unanswered in the first book. ▮

Editor's pick

Our leaders should use AI, but carefully

22 March, p 10

From Larry Stoter, The Narth, Monmouthshire, UK

I have no problem with government ministers using artificial intelligence to inform themselves. It is positive that UK minister Peter Kyle has done so and explained some of the topics he has explored. It is vital to understand some of the limitations.

I have used ChatGPT and learned two important lessons. First, the question you ask it needs to be specific and detailed, including a requirement for references. Ask a short, vague question, such as "how can I reduce the number of UK civil servants?", and it will almost certainly produce rubbish. Second, if your question is biased, the answer is likely to be so too. Asking "How can I reduce the number of UK civil servants?" presupposes that doing so is desirable – a bias. Much better, perhaps, to ask "In what ways might the cost effectiveness and efficiency of the UK civil service be improved?"

Back to the idea of a yo-yo universe

22 March, p 8

From Nigel Tuersley, Tisbury, Wiltshire, UK

Applying the same logic that gave rise to the big bang theory to the apparent slowdown in the accelerating expansion of the cosmos argues for a cyclical universe, in which expansion gives way to progressive contraction, and ultimately to an inconceivably dense, atom-like singularity of the sort that led to the big bang.

Humans have long been abusing technology

8 March, p 18

From Dyane Silvester, Arnside, Cumbria, UK

Annalee Newitz's comments, saying we shouldn't blame communication technology for authoritarian regimes abusing social media or the nightmare of AI chatbots generating lies, apply to most inventions. Tempering steel and splitting the atom had the potential to hugely improve our lives, but it didn't take long for us to kill one another using both. Any technology is only as good or as bad as the people who use it, and it seems to me that, as a species, we are particularly good at finding harmful (or, at best, banal and pointless) uses for new technologies, and then blaming the technology itself.

Getting sniffy about the future of nose jobs

15 March, p 22

From Wai Wong, Melbourne, Australia

The techniques involved in the futuristic "nose job" you imagined could have better uses than smell augmentation. Implanting programmed stem cells and reconnecting neurons could restore normal function to all sorts of organs, eliminating diabetes, paralysis, anosmia, blindness, hearing loss and more. Increased neuroplasticity could help with stroke, dementia and intellectual training. The nose job itself, however, sounds risky without the original sense of smell to fall back on. Better to leave smelling work to trained animals.

Little wonder creatures are natural healers

22 March, p 34

From Kate Phillipson, Prestbury, Gloucestershire, UK

The interview with Jaap de Roode made me wonder why people are surprised that animals do things to treat their ailments. Many have been around a lot longer than us and they have developed an understanding of the healing properties of plants, etc. Humans sought cures for the basic reason that they wanted to survive, so why shouldn't animals? And plants, for that matter. Sadly, people, particularly in the West, have lost a lot of the knowledge of what plants can do to help health, but animals, through necessity, are still using the natural pharmacy around them.

From Richard Brown, Huntly, Aberdeenshire, UK

This rekindled memories of the start of my veterinary career in north-east Scotland in 1981. It was common then for a suckler beef farm to have an area of "rough ground": a field of wild bushes, rushes, weeds and, simply put, whatever grew in that region that wasn't a tree. It was commonly used as a convalescence field for sick cattle, when appropriate. You would see them sniffing through the field looking for particular plants. My father-in-law, a farmer, assumed they were searching for foods that had herbal or medical benefit. These fields are almost all gone now.

How to fool even those savvy about illusions

22 March, p 15

From Brian Reffin Smith, Berlin, Germany

On the idea of learning to be less fooled by optical illusions, I do some lecture-performances to illusion-savvy audiences about 'pataphysics, art, zombie theory and so on. I tell them they just can't trust their brains, and build up to... the Müller-Lyer illusion, the one with two identical lines where one looks longer because of the direction of arrow heads. I ask them which is longer, and they can't believe I am ending on this old cliché! Smirking, they yell that they are both the same. But this time, they aren't. One is centimetres longer than the other. You can't trust your brain. You can have similar fun with cognitive scientists by showing a version of the famous disappearing gorilla video, the original suitably credited, edited to have no gorilla.

▮ The editor writes: See page 40 to read about the science of illusions

Old code is probably in your home right now

8 March, p 34

From Mel Earp, Macclesfield, Cheshire, UK

I enjoyed your look at old code, having written a fair bit myself in the programming language C. Some of that may well still run in home gadgets, maybe even your TV. It isn't just business systems that are powered by old code.

We didn't need Rome to make us civilised

Letters, 15 March

From Shonagh Potter, Edinburgh, UK

On the suggestion that civilisation is tied to domestic drainage, may I recommend that Trevor Prew take a trip to Orkney in Scotland, to visit the village of Skara Brae, where there is an example of such a system that predates the arrival of the sewer-loving Romans.

With time on their side, the aliens drew their plans

8 March, p 26

From Paul Douglas, Wellington, New Zealand

The void aliens will be coming to get timescape inventor David Wiltshire soon, well before the aliens of the galaxy clusters, who would be disadvantaged by gravity and a passing of 4 billion years less time (according to Wiltshire's idea) in which to develop their technology. ▮

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The secret superfood

From helping the gut thrive to dampening inflammation and even boosting mental health, we are finally uncovering how dietary fibre imparts its myriad benefits, says **Graham Lawton**

DEEP inside your lower intestine is a 24/7 dinner party. The trillions of microorganisms that live in your colon are feasting on foodstuffs you ate but failed to digest. Their motives are selfish but they are still doing you a favour, tending to the health of your gut, brain, heart and immune system.

Meanwhile, in the background, even-more-indigestible food is quietly drifting past. Even the microbes won't touch it, but it, too, has a positive effect on your health.

The name of all this undigested food? Fibre. Perhaps the most unglamorous of nutrients, it has so many things going for it that it deserves to be lauded as a superfood. But while the health benefits of a fibre-rich diet have been recognised since the 1950s, only in recent years have we gotten a firmer handle on the full complexity of this diverse substance and how to maximise these positive effects. New research is uncovering the power of different types of fibre to dampen inflammation, improve our immune function and mental health – and even act as "nature's Ozempic" by dialing down our appetite. These studies are also revealing why the fibre often added to processed food won't do the same trick.

Dietary fibre – also known as roughage – is defined as the portion of ingested food that cannot be broken down by our own digestive enzymes. You could be forgiven for thinking that all fibre is basically the same, just humdrum rough stuff that goes in at one end and ultimately comes out at the other. After all, food labels treat it as a single, monolithic entity; if they bother at all, most simply state how many grams of fibre a portion of the product contains.

LISA SHEEHAN

But fibre is not just fibre. "It is much more complex than other types of food," says Francine Marques at Monash University in Melbourne. Despite the monolithic label, "fibre" encompasses a hugely diverse mixture of plant-derived compounds. The majority are structural molecules from plants' rigid cell walls. These "non-starch polysaccharides" include cellulose, lignin, various hemicelluloses, pectin and others. The second, smaller category is resistant starch, which comes from energy-storing starch granules inside the cells.

Fibre thus runs the gamut from huge molecules such as cellulose, which can contain chains of carbon thousands of atoms long, to tiny sugar-like molecules with a carbon backbone of just three atoms. Different plants contain different amounts of these fibre types. Resistant starch is abundant in green bananas and legumes, for instance, whereas pectin is common in fruits. In turn, these fibres have distinct impacts on our health. "What we are discovering is that the different types of fibre have very different effects on metabolism," says Karen Madsen at the University of Alberta in Edmonton, Canada.

On top of this natural bounty, we are also increasingly obtaining fibre from unnatural sources. This includes either plant material ›

How to eat enough

Getting enough fibre in your diet is hard. Calculating your intake is no easier, especially because cooking and ripening can alter a food's fibre content (see "Fibre flex," page 33).

I tracked my fibre intake for a couple of weeks. Sometimes it was easy – packaged food usually listed the fibre content in grams per 100, while supermarket websites filled in most of the gaps on things like bakery items. I weighed my raw ingredients and calculated their fibre content using an online calculator. When I ate out, I had to estimate the fibre content from the calorie count on the menu; in this way, I could roughly calculate my overall fibre intake in grams. But drilling down into the different types of fibre is practically impossible.

My diet is mostly plant-based, so I expected to be close to, or over, the 30-gram recommended intake through my regular diet. But I wasn't – and I found I had to make a conscious effort. That involved a lot of oatcakes, nuts, dried fruit, baked beans on wholemeal toast, popcorn, hummus, avocados (surprisingly fibrous) and raspberries (ditto).

For five days straight, I smashed the target. I made more visits than usual to the loo and was bloated and flatulent – though I am told that these uncomfortable side effects decline as the microbiome adapts to a high-fibre diet. I was also very thirsty, presumably because fibre absorbs a lot of water in the colon. But I also found that my urge to snack declined and I lost a bit of weight.

that has been purified and processed, and entirely synthetic fibre, both of which are packaged into supplements or added to food. There are also animal sources of fibre, mainly chitin and chitosan from insect and crustacean exoskeletons, but these are not a significant component of Western diets.

Given this diversity, there have been attempts to break down the classification of fibre into smaller subunits. The most widely used distinction is whether a type of fibre is soluble in water. Cellulose and lignin, for example, don't dissolve in water and are classed as insoluble dietary fibre, while pectins, some hemicelluloses and many others are soluble. The thinking was that these two categories have different biological effects. But we now know that this distinction is neither clear-cut nor especially useful when considering their effects on human physiology, says John Mathers at Newcastle University, UK. A more useful subcategorisation, he says, is whether a fibre is fermentable: is it broken down by hungry microorganisms in the large intestine?

How much?

When we eat fibre, it passes through the mouth, oesophagus, stomach and small intestine largely untouched. Chewing can physically alter it – for example, breaking apart the plant cells to release fibrous molecules from their matrix – but, by definition, there are no enzymes to break it down.

It then reaches the large intestine, or colon, and the dinner party starts. This capacious organ doesn't secrete digestive enzymes of its own – but it is teeming with microbes that do, many of them capable of breaking down fibre. "Our microbes have over 1000 different enzymes that digest fibre," says Marques.

Even so, these microbes can only digest certain types of fibre, such as pectin and resistant starch, but not cellulose, which passes unfermented through the human gut. But the upshot is that the colon is essentially a fermentation vat for the chemical processing of tough plant material, producing energy for the microbes plus various interesting by-products – of which, more later.

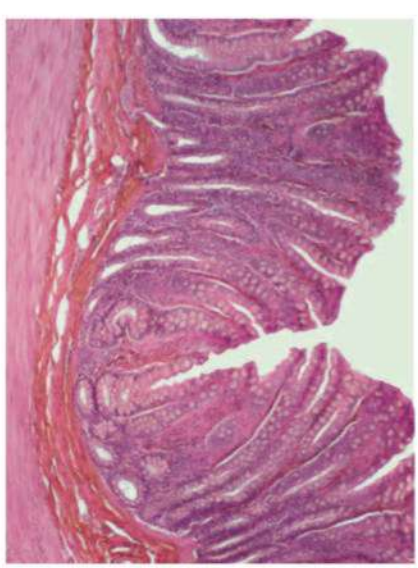
Beyond this, exactly what happens in the colon is a moveable feast. Diet composition varies widely from person to person and from day to day, making it hard to figure out what kind of fibre is doing what. "But we can predict that the different types of fibre will have quite fundamentally different effects," says Mathers.

If that wasn't complex enough, "everybody is going to respond to fibre differently because of the different microbes in their colon", says Madsen. This makes nailing down dietary fibre's precise effects extremely difficult. As a rough approximation, however, most of the fermentable fibre types are broken down by gut microbes, while unfermentable types glide through unaltered and are ultimately passed in stool. Both of these types of fibre have important roles in human health.

Epidemiological research has consistently found that eating adequate amounts of fibre protects against a range of health conditions including cardiovascular disease, stroke, type 2 diabetes and colorectal cancer. In 2015, the UK Scientific Advisory Committee on Nutrition found that adding 7 grams of fibre a day – about the amount in a portion of baked beans – to a person's diet produces a statistically significant reduction in their risk of developing all of these conditions.

The question then is: how much is enough? In 2019, a team of researchers led by Jim Mann at the University of Otago in Dunedin, New Zealand, pooled the results of 185 studies and

Fibre helps maintain the mucous layer (shown in dark purple) that lines our colon



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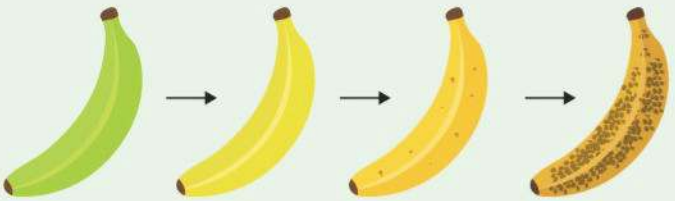
Fibre flex

Many things affect the fibre content of food, such as growing conditions, cooking, processing and ripening. For instance, the fibre content of bananas plummets during ripening due to resistant starch (a dietary fibre) being converted to digestible starch.



	Unripe	Slightly ripe	Ripe	Overripe
Total fibre	18g/100g	5.9g/100g	4.4g/100g	2.2g/100g

IMAGE USED FROM ADOBE STOCK

found that this risk reduction was greatest when consuming over 25 grams of fibre a day. People hitting that target showed a reduced risk of dying from all causes and also a significantly lower risk of coronary heart disease, type 2 diabetes and colorectal cancer.

As a result of these studies and others, most countries recommend that adults eat 25 to 35 grams of fibre a day. The average intake, however, is under 20 grams, and only around 20 per cent of people hit the 25-to-35-gram target, a persistent problem known as the "fibre gap". Filling this gap is hard (see "How to eat enough," left). "It takes an active effort," says Marques. "I'm someone who knows where to find fibre and I struggle to get the amount that I know I should be eating."

And while we know that fibre is good for us, epidemiological studies don't drill down into the mechanisms by which it exerts its positive effects. In recent years, there has been a huge effort to understand the complexities of dietary fibre and its interactions with the microbiome, in part to produce a more useful classification system, but also to find ways of getting more of the most beneficial fibre into people's diets.

Many of the positive health effects of fibre derive from its physical properties. One of the most important is that it absorbs and retains water, and can become viscous in the process. Some fibres, such as those from vegetables, can hold up to 25 times their own mass and volume of water; for fruits and grain fibres this figure drops to 13 and six times, respectively. In the stomach, this bulks up food and leads to feelings of fullness. It also delays the passage of food from the stomach into the small intestine, which extends the period of satiation after a meal. Both effects reduce the amount of food that we eat during and between meals.

"The colon is a fermentation vat for the chemical processing of tough plant material"

Lower down, the water-retaining fibre softens, enlarges and lubricates stools, aiding gut motility and producing a laxative effect. This guards against constipation, which is a suspected cause of colorectal cancer and which has recently been found to be a risk factor for hypertension and serious cardiovascular events, such as heart attacks and strokes. "Why that is the case, we are still trying to understand," says Marques.

Fibre also soaks up fat, cholesterol and glucose to varying degrees, depending on the type – fibre from walnuts, for instance, can absorb nearly 30 times its own mass worth of oil – reducing the absorption of these potentially harmful nutrients by the body. It does the same for bile acids secreted in the small intestine to help digest fat. Our bodies like to reabsorb and recycle bile acids, but a high-fibre diet forces the liver to synthesise new ones from cholesterol, reducing cholesterol levels in the bloodstream. And fibre is a natural chelating agent, picking up toxic heavy metals such as lead and helping to purge them from the gut.

For a long time, that was the extent of our understanding of fibre's positive health effects, says Madsen. But we now know that there is more to fibre than its physical prowess, evident in its interactions with the gut microbiome.

One of its jobs is maintaining the gut wall – something first recognised in 2016 in studies of mice. A healthy gut lining has a thick layer of mucus that helps to maintain "barrier function" – in other words, being in control of what passes from the gut into the bloodstream. "If we eat a lot of fibre, then bacteria in your gut will [eat the fibre and] leave this mucus alone," said Maria Vehreschild of Frankfurt University Hospital in Germany at a conference last year on the microbiome and ageing. "But if you stop doing that, they will start degrading the mucus because they need something to eat. Then, of course, the gut barrier is broken down." When this mucus is eroded, microorganisms can cross the gut barrier and enter the bloodstream. This jolts the immune system into action, resulting in low-level inflammation spreading throughout the body and an increased risk of high blood pressure; it also promotes obesity and metabolic dysfunction.

Breakdown benefits

Microbial fermentation of fibre also produces myriad chemical by-products with wide-ranging health benefits. Chief among them are three short-chained fatty acids (SCFAs) – acetate, propionate and butyrate – which increase acidity inside the gut, inhibiting the growth of harmful bacteria. But all three also bind to and activate a large and diverse class of receptors on cell surfaces called G protein-coupled receptors (GPCRs), initially within the gut but also throughout the body once they have diffused into the bloodstream.

One of the key interactions between SCFAs and receptors in the gut triggers the release of two appetite-suppressing hormones: PYY and GLP-1. The latter is mimicked by the new generation of weight-loss drugs, leading fibre to be dubbed "nature's Ozempic". PYY release is also stimulated in the ileum – the final segment of the small intestine – by a dietary fibre called stachyose, found mainly in legumes such as beans and lentils, according to research published last year by Gary Frost at Imperial College London and his colleagues.

As well as this, we now also know that SCFAs stimulate a gut receptor that helps to maintain barrier function. This is another reason why low-fibre diets can lead to inflammation, says Marques. ›

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Vegetables and fruit offer a cornucopia of different dietary fibres

Once in the bloodstream, SCFAs travel to all parts of the body, including the brain. "They're wonderful metabolites," says Madsen. Among their many and varied beneficial effects, they have been shown to boost immune function, further reduce inflammation and protect against dementia and metabolic diseases such as type 2 diabetes. Given the link that exists between chronic inflammation and depression, SCFAs may explain the findings of a yet-to-be-published study by Madsen and her colleagues, which showed that eating a five-day, high-fibre diet once a month can reduce symptoms of depression and anxiety.

Eating more fibre also changes the composition of the gut microbiome, possibly for the better – though exactly which types of microbes make for a healthier microbiome is the subject of much debate.

Unfortunately, translating these new discoveries into actionable dietary advice is challenging. Many nutritionists hope that we will one day be able to stop lumping all fibre together and offer more fine-tuned advice – perhaps stating what proportion of the fibre is a good source of SCFAs, much as food labels say how much of the fat is saturated and how much of the carbs are sugars. "I think we are heading towards that," says Mathers. "But I am not sure we have enough detailed information to do it yet."

For now, then, the existing nutritional advice stands – but with some useful embellishments. Thirty grams of fibre a day is still a good target, but not just comprising any old fibre. Cover as many of the bases as possible – fruits, vegetables, pulses, nuts, seeds and wholegrains. Then you are hedging your bets on getting adequate amounts of the full range of fibres. And don't worry about eating too much: "There is no downside," says Marques. "You might get to a threshold where you are not getting any additional benefit, but you are not going to have a health issue because you have too much fibre." Unless, that is, you have a bowel condition such as Crohn's or inflammatory bowel disease, where excess fibre might trigger an episode.

It is also advisable to obtain fibre from whole foods rather than relying on supplements or processed foods fortified with fibre, which often contain just a few types. "A commercial fibre supplement doesn't give you the same portfolio of dietary fibres, and we think that portfolio is really important," says Frost. Supplements also lack the complex structure of the fibres found in whole plants, which is increasingly seen as being important to their health effects. "We think that the cell structure does play an important role when the food goes into the colon," says Frost. For one thing, it enhances the release of the satiety hormones PYY and GLP-1 , he says. For these reasons, synthetic fibres, which are increasingly added to processed foods to make them appear to be a good source of fibre, are also likely to be suboptimal. "We have no idea whether they are actually beneficial," says Mathers.

Another reason for opting for a range of fibre-rich whole foods is that these also contain lots of other plant-based benefits such as vitamins, antioxidants and unrefined (but digestible) carbohydrates. In fact, these nutrients might be part of the reason behind the epidemiological evidence showing that diets rich in fibre are so beneficial. "Whether it's the fibre per se or whether it's a diet which contains lots of fibre is something which has never fully been resolved," says Mathers.

Even so, the message remains the same: "It's clear that high-fibre diets prevent chronic diseases," says Madsen. So if you don't already eat 30 grams of fibre a day, it is time to get the party started. ▮

Graham Lawton is a staff writer at *New Scientist*

Fibre hacks

The word "fibre" usually evokes images of All-Bran, lentils, brown rice and other virtuous (though not necessarily tempting) foodstuffs. But some delicious and healthy foods deliver surprising amounts of fibre.

Avocados, for example, contain 6.7 grams of fibre per 100 grams, enough to get them over the 6-gram threshold needed to be called a high-fibre food. Passion fruit clocks up 10 grams and raspberries tout 9.1. Popcorn has an eye-popping 14 grams, almost half of your daily target in a 100-gram bowl (though that is admittedly a lot of popcorn). By the same token, some foods that you might assume are very fibrous are not. Celery, for instance, contains just 1.5 grams; cabbage has 1.7. In fact, from a fibre perspective, you would be better off eating potato chips (around 3.9 grams) and dark chocolate (around 6 grams).

White pasta and rice don't contain much fibre when freshly cooked, but when cooled, their starch crystallises into a form of fibre called resistant starch, which remains intact when you reheat it.

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The power of one

A solitary lifestyle has surprising advantages for some animals and could even give us insights into human sociality, finds **Sam Wong**

PAUL SOUDERS/GETTY IMAGES

LONESOME GEORGE, the last of the Pinta Island tortoises, died in 2012, leaving no offspring. His solitude was imposed upon him by humans who killed the rest of his species and brought goats to his island in the Galapagos, destroying their habitat. But Lonesome George probably didn't much mind being on his own. Tortoises are generally solitary, coming together only to mate. The same is true of most reptiles and even many mammals, including bears, moose, tigers, sloths, platypuses, rhinos and pangolins.

As social creatures ourselves, it is only natural that we are fascinated by animal societies, from wolf packs to ant colonies. But to understand sociality, we must look at the flip side: why do some animals prefer to go it alone? Surprisingly, researchers have paid little attention to this question. "People are only interested in group-living species with complex societies," says Carsten Schradin at the Hubert Curien Pluridisciplinary Institute in Strasbourg, France. "But if you don't understand why, in many cases, solitary living is the better solution, you also miss a total understanding of group living."

Now, Schradin and a handful of pioneering biologists are addressing this oversight. Already, their research reveals that being solitary isn't simply the ancestral lifestyle for mammals, but an evolved strategy, a specialised way of living, with its own pros and cons. What's more, animals considered solitary aren't necessarily antisocial: it turns out that many of them have structured social networks, even if they spend most of their time by themselves. These creatures give us a new perspective on sociality, helping us see why other animals, including humans, evolved to live together.

Biologists have long assumed that being solitary was a primitive state in the evolution of animals needing no special explanation. Mammals evolved from reptiles around 225 million years ago, so, like their reptilian forebears the cynodonts, these small, shrew-like creatures were thought to live alone. And this lifestyle was believed to have largely persisted to this day. "I grew up with the idea that, because most mammals are small, most are solitary living," says Schradin. These assumptions seemed to be confirmed by a 2013 study indicating that 68 per cent of mammalian species are solitary.

However, many of the supposed asocial species in the analysis hadn't been studied in the wild because they are nocturnal or elusive. So, Schradin decided to take a closer look at the evidence. Working with Lindelani Makuya at the University of the Witwatersrand in South Africa, he focused only on mammals for which there was reliable information in natural populations. The research, published last year, found that less than a quarter – only 131 out of 592 species – were mainly solitary, defined as both adult males and females sleeping and foraging alone most of the time.

The relative rarity of solitary living suggests it may not have been the lifestyle of the common ancestor of all mammals after all. Indeed, some fossil evidence adds weight to this idea: early cynodonts lived in burrows around 250 million years ago and some of these have been found to contain the fossilised remains of several adults or adults with offspring, hinting at group living. Recent research in primates also supports the idea. The common ancestor of all primates was a small, nocturnal animal that lived in trees. Lemurs are among their closest living descendants, emerging some 70 million years ago, and although they are generally considered to be solitary, Schradin and his colleagues found that they are, in fact, quite sociable. Furthermore, when they analysed field data from 493 populations of 215 primate species, it emerged that going solo was the primary way of life in just 3 per cent of populations and 6 per cent of species. Some other species were solitary foragers, but they shared their home range or sleeping site in pairs or groups. Based on these lifestyles of modern primates, the researchers concluded that their earliest ancestors were most likely to have lived in pairs.

If solitary living isn't the ancestral state of primates or other mammals, then it must have evolved as an adaptation to specific environments. So, what kind of environment drives animals towards this lifestyle? In an attempt to answer that question, some biologists have turned to social animals, which they know far more about.

One idea that has been put forward to ›

explain why animals group together is called the resource dispersion hypothesis. If food is plentiful in localised patches and sparse elsewhere, those patches can feed many animals, and they will form groups to defend their resources. To flip this around, if food is evenly distributed and not shareable, that might favour living alone. A 2024 study found support for this hypothesis among martens and related animals, a group of carnivores considered to be highly solitary. Joshua Twining, then at Cornell University, New York, and his colleagues analysed camera trap data from seven species across the world, taking the likelihood of animals appearing on camera in groups as a measure of their sociality. There was wide variation among them, with the yellow-throated marten (*Martes flavigula*) of East and South-East Asia seemingly the most sociable of the bunch. Crucially, though, the sociality of each species was linked to food distribution, with animals more likely to form groups if they relied on patchy resources such as fruit, insect nests and large prey.

Why go solo?

Nevertheless, this principle doesn't explain all the variety in social systems between related species, says Peter Kappeler at the University of Göttingen in Germany. He has been studying eight lemur species in Madagascar for 30 years. "They're in the same forest. They're literally sitting in the same trees. Two of them are group living, three of them are pair living and three of them are solitary," he says. "Maybe they're feeding on slightly different things, but there's nothing obvious that would come to mind [to explain their different social systems]."

Another factor commonly cited as a reason for group living is the risk of predation: strength in numbers can protect you from being eaten. But this is only really true for large animals, says Schradin. "Even when there are 100 small mice, they can do nothing against a jackal or a bird of prey." For smaller animals, being a loner can be the safer option because you are harder to spot. Group-living animals must also cover long distances to forage, whereas going solo means you can find food within a small area, which reduces your risk of predation while moving around. Again, this can't be the whole story because going solo can be a successful strategy for predators too. An estimated 80 per cent or more of species in the order Carnivora, which includes cats, dogs and bears, are described as solitary, socialising only to mate and bring up young.

While food resources and predation risk might explain why some animals have evolved to be solitary, another possibility is that it brings some surprising benefits. Foraging in a smaller range, for example, means that an individual doesn't need to expend so much energy in search of food. Schradin and Makuya propose that this is one of the three main advantages of solitary living. The second is that living alone reduces your chance of picking up parasites or infections. Third, being a loner also means you avoid the stress that comes with social interactions – including competition over mating. Loners have a better chance of reproducing, especially compared with gregarious species, such as meerkats, where a few dominant individuals tend to monopolise mating.

"Many of these solitary animals have a kind of social network that we have no idea about"

As well as different possible reasons for going it alone, it turns out there are different ways of being solitary. For a start, there is huge variation in how aggressive solitary animals are to other individuals. Hamster mothers, for example, even attack their own offspring when they reach maturity and chase them away, whereas bush Karoo rats (*Myotomys unisulcatus*) are far more accommodating. They live in a semi-desert region of South Africa and are solitary most of the time, but they form small family groups after the breeding season. The rats build stick lodges and offspring inherit these from their mothers, so rats that live near each other tend to be related and they share feeding grounds. "They are also very tolerant of each other," says Makuya, who studies them. "This is in contrast to what is believed about solitary species, that they are solitary because they are aggressive."

In fact, many apparent loners turn out to have hidden social lives. One of the most surprising examples comes from a study of pumas. Camera traps and GPS data showed they frequently shared their kills with unrelated individuals – and the beneficiaries often reciprocated. Brown bears can be surprisingly social too. When a team led by Rick Heeres at the University of South-Eastern Norway analysed GPS tracking data from 153 bears in Sweden, most of the interactions were found to be meetings between males and females during the mating season. However, the researchers also saw males and females and family groups socialising throughout the year. "When they're not hibernating, they seem to be associating with multiple individuals," says Heeres. "But we don't know what the reason is for these associations that

DAVE WATTS/ALAMY

Species of solitary mammal, which include platypuses, lemurs and pumas, are far less common than biologists thought

happen outside the mating season." Perhaps males are keeping an eye on their rivals or checking out females that will soon be ready to mate. Another possibility is that they are congregating around food sources. In North America, this happens at salmon streams and garbage dumps, he notes, although such features weren't present in his study area.

"I think because solitary animals are so elusive most of the time, we have underestimated their sociality in general," says Heeres. They may interact in ways that are less obvious, through scents and sounds, for example. "I think that's one of the biggest gaps in what we should learn from them. I think we would find some remarkable examples – that these solitary animals are having a whole kind of [social] network that we have no idea about." Kappeler makes a similar point. "I don't think we have a full understanding of the variation that exists out there," he says. "Certainly, only a tiny minority of species is truly solitary." Given what we now know, he suggests that labels like solitary and group-living may be too simplistic.

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The social brain

A better understanding of how other animals live won't just reveal unexpected variety and clarify the evolutionary origins of their social lives, it could also shed light on the neurological mechanisms that control social and antisocial behaviour. "One of the motivations for studying solitary behaviour is that even in social creatures like us, not everyone is social at the same level. We have a spectrum," says Tali Kimchi at the Weizmann Institute of Science in Israel. Some of us suffer when we are cut off from other people, as we were during covid-19 lockdowns, for instance, whereas others are much happier on their own. Traditionally, mice and rats have been used as a lab model to study the mechanisms that control human social behaviour because they share much of our genetics, neurology and physiology. However, both are social animals. To get the full picture, we need to look at a range of species with different degrees of sociality, says Kimchi. "I think if we understand this in animals, we can understand better about social-related neuropsychological conditions [such as autism]," she says. "It can give us more hints where to look."

Mole rats might be a good place to start because seemingly similar species can have very different social lives. Middle East blind mole rats (*Spalax ehrenbergi*), for example, are hypersolitary. They live alone in underground tunnels and are extremely hostile to others. "If they accidentally interact, one of them will be injured or even dead," says Kimchi. This is in stark contrast to naked mole rats (*Heterocephalus glaber*). They have a similar subterranean lifestyle, but live in colonies with dozens or hundreds of individuals. Like those of some ants and bees, these colonies have a queen and a small number of breeding males, while the rest are workers. Why the two species are so different is still a mystery, but Kimchi suggests we should look at them another way. "You can think about [the colony] as a superorganism. And this superorganism has a solitary lifestyle," she says. Although the colony residents tolerate one another, they attack and kill invaders from other colonies with as much aggression as blind mole rats display towards other individuals. This raises interesting questions about the extent and power of sociality that might also be relevant to our relationships.

So much about solitary animals remains to be discovered. And the potential payoffs of this research are intriguing. To help us get closer to understanding why some animals club together while others go it alone, Makuya and Schradin have recently set up a virtual scientific community where researchers can share their findings and ideas. "There are more and more people studying solitary species and coming up with the correct questions, but they're not connected yet," says Schradin. He believes that with more knowledge about these creatures, we will be better able to protect them. Like Kimchi, he also thinks studying them can help us understand ourselves.

"One big lesson is that you don't have to be asocial to be solitary," says Schradin. "You can live alone but still have meaningful social interactions with your neighbours." For humans, social isolation is strongly linked to ill health, but we can also benefit from spending time alone, and solitary animals could help us better understand these benefits. "Maybe we should see that, for some people, or for yourself at some stages of your life, it's also OK if you're looking to be left alone and to avoid social conflict." ▮

SEBASTIAN KENNERKNECHT/MINDEN/NATUREPL.COM

Sam Wong is a news editor at *New Scientist*

Magicology

Psychologists are looking to magic tricks to understand how our brains make sense of the world around us. But, asks **David Robson**, is the science of magic simply another illusion?

WHEN Gustav Kuhn was 13, a friend pulled an egg out of his ear.

Kuhn was astounded – but his wonder didn't abate, even after he learned that the egg was made of foam and had been easily hidden in his friend's hand.

"I was quite fascinated by those eggs," he recalls. The trick sparked an obsession with how the brain can be hoodwinked into believing the impossible. "My whole life during my teenage years was centred [on] magic and deception," he says. "I became completely addicted."

Kuhn's adolescent fascination eventually led to a career in magic – although he hasn't exactly followed the trajectory he had in mind at 13. Though he is a practising magician, he is primarily a psychologist, working to understand what the cognitive quirks that lead us to percieve a rabbit being pulled from a hat or a levitating £5 note can reveal about the brain. "I've been trying to create the science of magic, which uses [tricks] as a way of exploring the human mind", Kuhn says.

It seems to be working – more than 150 "science of magic" papers have been published since the late 2000s. This research attempts to peel back the layers of conscious experience to demonstrate how expectation seems to control our perception of reality and how easily we can be led into making decisions while retaining a sense of agency.

The field, though, has attracted criticism from members of both disciplines. Some scientists worry that it lacks rigour, while some magicians are concerned that these experiments strip the mystery from their tricks. Is the science of magic itself just a beautiful illusion – or can it reveal something profound about how our minds work?

The inclination to bring magic and science together has a strong historical precedent. Alfred Binet, a *fin-de-siècle* psychologist who invented the first intelligence test, was particularly fascinated by illusionists' prestidigitation, or sleight of hand. Binet suspected that they created their illusions by shifting their fingers too fast for the eye to perceive. To capture their movements, he turned to a new technique, chronophotography, a precursor to film cinematography that took successive images of a subject in motion, at a rate of one every 10th of a second.

In his resulting 1894 paper, "The Psychology of Prestidigitation", Binet reported that the illusions disappeared when observers watched the slowed-down, silent clips. Without the performer's speed, patter and showmanship, there was no magic. Binet concluded that the tricks relied on mental processes like attention, noting, "Prestidigitation rests on psychology."

Like magic

But such observations would be more or less ignored by psychologists for a century – a source of frustration to Kuhn as he embarked on his career. In 2008, he co-wrote a review paper for the influential journal *Trends in Cognitive Sciences*, urging other psychologists to find inspiration in magicians' illusions. "Although a few attempts were made in the distant past to draw links between magic and human cognition, this knowledge has been largely neglected by modern psychology," argued Kuhn and his co-authors. "We propose that the time has come to examine these phenomena more closely, and to connect them to current theories and methodologies for exploring the human mind."

So Kuhn and other like-minded scientists did exactly this, starting with the same kinds of illusions that Binet examined. A classic deception known as the "vanishing ball illusion" – already well-known when Binet discussed it in 1894 – provides an ideal example. In this trick, a magician repeatedly tosses and catches a ball. At one point, they make the same movement, but, having concealed the ball in a pocket or with their hands, they don't throw it. Quite remarkably, most spectators report seeing the ball fly up into the air before it vanishes into nothing.

The effect can be startling. "It produces a distinct feeling that's more than just basic surprise," says Geoff Cole, a psychology researcher at the University of Essex, UK. "It really does look like it's disappeared."

The illusion is thought to work because of "predictive processing", a theory of consciousness that is gaining ground among cognitive neuroscientists, psychologists and others. This framework suggests that the brain is constantly making predictions about the world around us to inform complex simulations that help it make sense of the imperfect data gathered by our sensory organs. Our experience of reality is dictated by these mental models. Most of the time, they match what is occurring in the real world – but they can sometimes make incorrect predictions, producing a sense of something that isn't there. In this case, the expectation that the ball will rise out of the magician's hand creates a ›

PHILIP HARRIS

New Scientist video
Watch Gustav Kuhn show off his mind-bending magic tricks newscientist.com/video

MARIE LAFAUCI/GETTY IMAGES

split-second impression that it is rising in front of us. When the data from our eyes catches up with the brain's simulations and corrects them, the perception of the ball vanishes while it is in mid-air.

"We don't have a picture of the world as it is," says Cyril Thomas, a cognitive psychologist at the Marie and Louis Pasteur University in Besançon, France. "We add a little bit of anticipation."

Tricks like the vanishing ball illusion demonstrate just how easy it is to prime the brain's simulations. Kuhn, for instance, found that around a third of people will experience the illusion with a single fake throw, for instance, without any of the usual ball-tossing beforehand.

One theory had been that social cues drive the participants' expectations. In the classic vanishing ball illusion, the magician raises their eyes as if they are following its trajectory, which was thought to help prime the illusion. Thomas, however, has since shown that it works just as well if the performer's face is hidden behind a mask. "Their gaze is not the main factor here," he says.

The "phantom vanish magic trick" shows that it is even possible to create the illusion of a completely non-existent object, which then disappears mid-performance. This illusion, which tests the limits of our brain's predictive models, is the invention of Matthew Tompkins, a cognitive science researcher at Lund University in Sweden. In a video, Tompkins pantomimes taking an object out of a cup and placing it in a closed fist. He then clicks the fingers of the other hand and opens his fist to reveal a clean palm. Of the 420 participants, 136 – or about 32 per cent – reported having a visual impression of the phantom object. For some, it was a fleeting experience that was difficult to describe, but others went as far as to note its non-existent shape and colour.

Their minds may have constructed some of these details after the event, or the participants may have actually "seen" them in a kind of controlled hallucination. Either way, this demonstrates the brain's ability to fill in small gaps in its perception, which could be useful in day-to-day life to form a coherant view of reality, like adding a missing word to a sentence whose entirety you didn't quite catch. "Magic is exploiting otherwise adaptive processes," says Tompkins.

Sceptics might suggest that the participants weren't being totally honest or that they had simply reported seeing something magical because they knew that is what the researchers expected them to see. This didn't appear to be the case, however. When they watched a control video of Tompkins elaborately placing a coin in his mouth, they were distinctly unimpressed. Their reports of the phantom vanish magic trick appear to have been genuine, reflecting a momentary glitch in the brain's elaborate constructions of the world around it. Such errors may happen all the time without us even noticing them.

It seems that many of our everyday experiences may need a reality check – and that could extend to the times we believe we are exercising free will. Consider a basic card trick, in which a participant is asked to pick from a selection of cards in front of them. The magician wows the audience by naming the suit and number before the card is even turned over. In such cases, the magician will have applied a "forcing" technique to ensure that their mark picked a pre-determined card. The choice looks random to everyone except the performer, who has been dictating the selection all along.

Pick a card, any card

Some forcing techniques rely on the inherent predictability of our behaviour. Imagine, for instance, that a magician lays four cards in front of you. Which would you select? If your choice was totally random, there would be a 25 per cent chance of choosing each one – but Kuhn and his colleagues have found that around 60 per cent of right-handed people opt for the third from the left, since it is the easiest to reach.

Most stage magicians would rely on more sophisticated manipulation. Illusionist Derren Brown, for instance, became famous for his ability to plant the idea of a particular card in participants' minds. To examine this scientifically, Kuhn's colleague Alice Pailhès recorded a video with the following script. "I'm going to try to transmit to you the identity of this card," she says, while holding up a card with its back facing the camera. "Imagine a screen in your mind, and on this screen, the little numbers low at the bottom of the card, in the corners, and at the top, and then the things in the middle, in the centre of the card... and in the middle of the card." The viewer then writes down what was in their mind.

The words give very little away. Pailhès's presentation, however, incorporates some non-verbal signals that are designed to lead the person watching towards picking the three of diamonds. While asking them to picture a screen, for instance, she makes a diamond sign with her fingers; she also draws the figure 3 in the air while describing the numbers on the card.

If you are sceptical that such tiny gestures could influence anyone's behaviour, you aren't alone: "I was convinced it wouldn't work," says Kuhn. He was happily proved

FLORILEGIUS/ALAMY

Magic relies on quirks in our attention and perception

Choosing a card actually involves little free choice

wrong. The probability of selecting the three of diamonds at random is 1 in 52, or 1.9 per cent, but around 10 times that figure – 17.8 per cent of the participants – chose the card. Even if they didn't get the exact combination, they were considerably more likely than chance to pick either the correct suit (33.3 per cent) or the correct number (38.9 per cent). "Unconscious priming is super rare, and the effects are generally quite small," says Kuhn. "So I was very surprised by how reliable that effect was."

Crucially, the participants had no idea that they were being manipulated, believing their choices were entirely theirs. Kuhn describes this as an "illusion of agency", and it is most powerfully demonstrated with the "equivoque forcing technique". Once again, the participant is given four potential cards, face down. They are first asked to narrow the choice by touching two cards, after which a pair is removed from the table. They repeat the same process, selecting one of the two cards, one of which is removed. The magician will then turn over the remaining card to reveal that it is the one that they had predicted.

If this description sounds vague, that is deliberate. Rather than asking them to "pick" or "choose" the cards, the magician asks the volunteer to "touch" them in each round. Without explicitly explaining whether the selected cards will be left or discarded, the magician can proceed however they want. If the volunteer touches the cards the magician wants, they keep them on the table; if not, they discard them. In this way, the magician can ensure that the desired card is the last one remaining.

The ruse seems obvious when it is spelled out in this way. Yet Kuhn and Pailhès have found that almost all people believe that they had some control over the card they chose. "They are not aware that their decisions have no impact on the outcome," says Kuhn. The illusion of agency appears to be so strong that it remains after an immediate repetition of the trick. Despite going through the same procedure a second time, the participants are still none the wiser about the trick's mechanisms.

> "Magic is exploiting otherwise adaptive [brain] processes"

Such replicable findings have helped to move the science of magic out of its infancy and into adolescence. It is also important to note that many of these experiments necessarily lack some of the showmanship of stage tricks. Though this has occasionally raised the eyebrows of professional performers, it is in aid of the "science" part of the science of magic. "We have to reduce a lot of variables so you can work out the contribution of a specific method," says Tompkins.

But the development of the science of magic has been accompanied by some growing pains. Cole, for instance, is concerned about the rigours of the field. He argues that some papers have failed to apply some of the basic principles of good research, such as controlling for confounding factors. "It's gone too much towards the magic paradigm," he says. Richard Wiseman at the University of Hertfordshire in the UK, meanwhile, questions the originality of the recent research, including some of the perceptual illusions. "They're very neat applications of things that psychologists already know about, but I'm not certain they're bringing very much new to the party, though they are very good for teaching."

Kuhn readily admits that the quality of the research varies – as it does in other fields – but notes that the science of magic is already inspiring novel approaches in seemingly unrelated fields. Amory Danek's primary interest, for instance, is in problem-solving, particularly those "aha moments" when inspiration strikes. Experiments in this field often use anagrams and geometrical puzzles, but Danek, a theoretical psychologist at Heidelberg University in Germany, has found that asking people to solve magic tricks tends to produce better results. "They're a very strong stimulus," she says. "People really want to know how they are done."

Her work shows that the strong sense of reward that accompanies the moment of insight brings a major memory boost – a finding with immediate implications for education. "Ideally, we would have teachers setting the stage so pupils can have their own aha moments," she says.

Kuhn is expanding on these findings. "We're combining magic tricks with neuroimaging to give the illusion that we can insert thoughts and looking at the impact that that can have on people's creativity," he explains.

That is just one of many projects exploring the possibilities of the science of magic. Another will explore the parallels between magicians' tricks and those used by fraudsters. "I think there is a lot of scope to use magic as a way of enhancing critical thinking and raising awareness of the deception that happens in our everyday lives," says Kuhn.

Twenty-five years into his career, Kuhn isn't as fascinated by foam eggs as he once was. But he has lost none of his enthusiasm for magic and for most people, he says, knowing how the trick is done – understanding the psychological explanations of the phenomena – doesn't ruin the enchantment. In fact, it only inspires greater awe and wonder: "I love magic, and I strongly believe that we are only enhancing the art." ▮

David Robson is a science writer and the author of *The Laws of Connection: 13 social strategies to transform your life*

Puzzles
Try our crossword, quick quiz and logic puzzle p45

***Almost* the last word**
How exactly does one entangle two photons? p46

Tom Gauld for *New Scientist*
A cartoonist's take on the world p47

Feedback
Alice and Bob, meet Pete Hegseth and Michael Waltz p48

Twisteddoodles for *New Scientist*
Picturing the lighter side of life p48

Stargazing at home

Small but mighty

Pluto isn't the solar system's only dwarf planet – and we are about to get a chance to spot one of the strangest, says **Abigail Beall**

Abigail Beall is a features editor at *New Scientist* and author of *The Art of Urban Astronomy*. Follow her @abbybeall

What you need

A telescope with an aperture of at least 25 centimetres

I FIND the outer reaches of our solar system fascinating. It's a place that we know very little about considering how relatively close it is – even its size is up for debate. It's littered with icy rocks, most of which are detectable only by huge telescopes. But soon we will have a chance to spot one of these strange worlds.

Pluto is undoubtedly the most famous of all the dwarf planets, because it was once considered part of the main lineup of planets in our solar system. But there are four other dwarf planets officially recognised by the International Astronomical Union. Unlike the planets, most of which are easy to spot with the naked eye, finding the dwarf planets is tricky to do and requires a telescope.

Perhaps the strangest of them all, Haumea, is at opposition on 22 April. This means it is on the same side of the sun as Earth. In other words, Earth sits perfectly in between the sun and Haumea, making it the ideal time to look for it in the night sky as its rocky body reflects sunlight back at us.

The egg-shaped dwarf planet, also known as 2003 EL61, was the first of its kind to be found since Pluto was discovered in 1930. Its discovery sparked controversy, as two teams of astronomers claimed to have found it – one that first spotted it in 2003 and another that first announced it in 2005. It took a few more years before the tiny world was named Haumea, after the Hawaiian goddess of fertility.

Haumea is a curious rock. At about one-seventh the size of Earth, with an equatorial diameter of around 1700 kilometres, it is roughly the same size as Pluto. But it is one of the fastest-spinning large objects in the solar system, rotating every 4 hours, and it takes 285 years to orbit the sun from its location far beyond Neptune in an icy region called the Kuiper belt. It has two known moons and a ring that was discovered in 2017, making it the first known Kuiper belt object to have any rings.

SCIENCE PHOTO LIBRARY/ALAMY

Finding Haumea isn't easy. The best time to look is around 22 April, when its opposition coincides with its closest approach to Earth, so it will be at its brightest. You will need a telescope with an aperture of at least 25 centimetres, and even then it will look like a point of light. Long-exposure astrophotography is the only way to make out its oval shape, shown in the illustration above.

It will be near the bright star Arcturus, in the constellation Boötes, reaching the highest point in the sky around midnight from anywhere in the world. Viewers in the northern hemisphere, like me, will be able to see it all night; from the southern hemisphere, it will be visible most of the night.

I first glimpsed Haumea a few years ago. Although it just looks like a speck of light, I found it really exciting to look at, knowing it is part of our own solar system. It felt more familiar, somehow, than the distant stars or galaxies I'm used to finding with my telescope. ▮

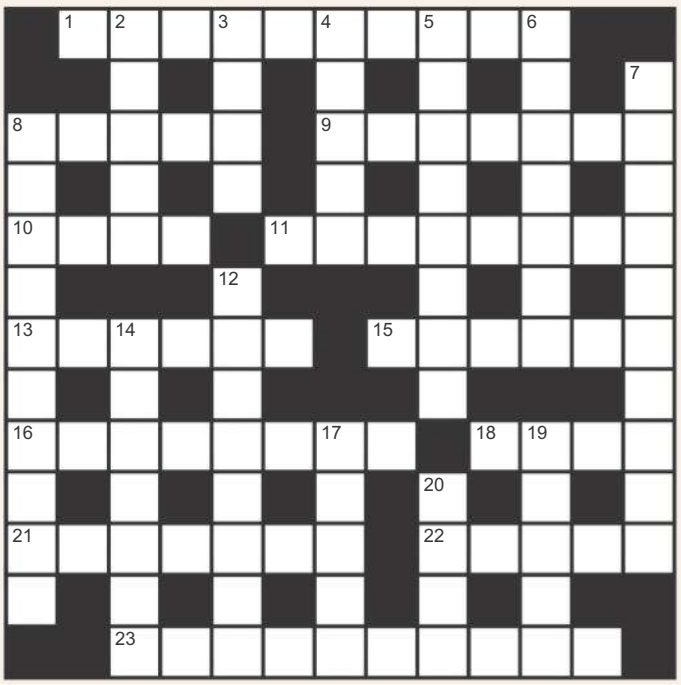
Stargazing at home appears monthly

Next week

Mathematics of life

These articles are posted each week at newscientist.com/maker

Cryptic crossword #159 *Set by Rasa*



Scribble zone

Answers and the next quick crossword next week

ACROSS

1 Reading material for each graduate inside bags (10)
8 Run and run, following six stars making a picture (5)
9 Found in a river vessel used by a virologist? (7)
10 Mesh traps white semiaquatic creature (4)
11 Stand next to one working charger, perhaps (8)
13 Feel true belonging amid people of the Arctic (6)
15 Heaviness of tungsten cube (6)
16 Sun-kissed fellow's digressions (8)
18 Turn black automobile outside hospital (4)
21 Again put on new player with double the pressure (7)
22 Experiment at CERN in trial phase (5)
23 Mathematician rambled on, wasted time (10)

DOWN

2 Pointer male lacking in bone tissue (6)
3 Functional group isolated the wrong way (4)
4 Tad grips iron, flipping suit (5)
5 Harsher drug put into fried pastry (8)
6 Beginning to suspect irrational horror novelist is punching down? (7)
7 Special theatres schedule extremely elegant diva's performance (10)
8 Engineer delivery vehicle, then start carrying it (10)
12 Delicate spine hurt in the course of sport (8)
14 Male cat keeps close to record player part (4,3)
17 Aromatic occasion for the audience (5)
19 Massive animal joint located by petty officer (5)
20 Block bee stinger (4)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #297
set by Corryn Wetzel

1 Titan is a moon of which planet?

2 What are the offspring of hedgehogs called?

3 What chemical compound is responsible for the red colour of beetroot?

4 Which physicist first proposed the idea of a wave-particle duality of matter?

5 Which of these metals can melt in the warmth of your hand: gallium, tin, sodium or bismuth?

Answers on page 47

BrainTwister
set by Peter Rowlett
#68 Another 2025 puzzle

The square root of 2025 is 45. The divisors of 45 (apart from 45 itself) are 1, 3, 5, 9 and 15. The product of these numbers is 2025.

The last year that was a square number was 1936. Does 1936 also have this property?

What is the smallest square number with this property? Does it work for all square numbers?

Solution next week

Easy entangle

Quantum physicists talk a lot about entanglement. How exactly does one entangle two photons? And can I try it at home?

Mike Follows
Sutton Coldfield, West Midlands, UK

One method of entangling two photons involves using a laser and a process known as spontaneous parametric down-conversion. When a high-energy photon from a laser interacts with a specially designed nonlinear crystal, it splits into two lower-energy photons. These are generally created in an entangled state in terms of their polarisation, momentum or other properties. For instance, momentum is conserved, meaning the total momentum of the entangled photons remains equal to that of the original photon.

There is more than one philosophical interpretation of quantum mechanics, partly due to the fuzziness imposed by Werner Heisenberg's uncertainty principle, which says we can't precisely measure both the momentum and the position of a particle. One interpretation is that a particle only has clear-cut properties when it is observed. Albert Einstein challenged this: along with Boris Podolsky and Nathan Rosen, he proposed the so-called EPR thought experiment in 1935. The idea was that a particle could split into two, with the resulting halves moving in opposite directions.

"This isn't something you could set up in your living room, but entanglement is happening all around us"

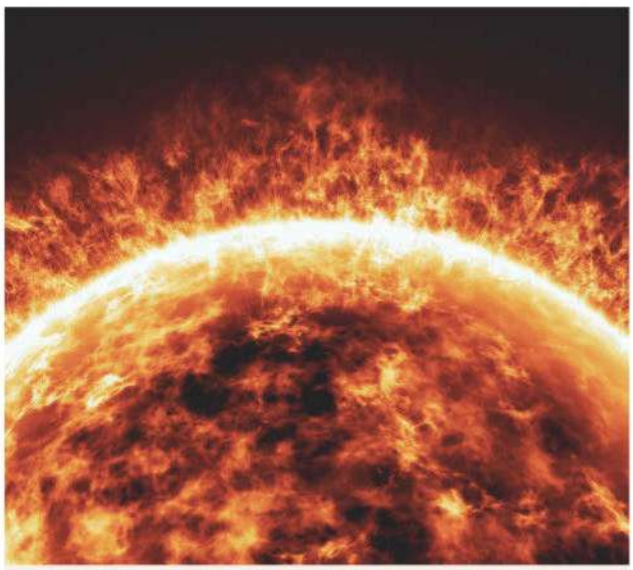
Based on our understanding of the quantum mechanics of entangled particles, by measuring the properties of one particle, conservation laws could be used to infer the properties of the second without directly observing it. Furthermore, changing the properties of one particle would instantly change those of the other particle – no matter how far away it is. This would mean that information passing between the particles might need to travel faster than the speed of light. That appeared to contradict Einstein's theories of relativity, leading him to reject what he termed "spooky action at a distance" and what we call quantum entanglement.

Alain Aspect used a laser to perform the first definitive test of what became known as the EPR paradox in 1982 to prove that particles can indeed be entangled. Scientists reconcile it with relativity by saying that it is information, not matter, that is being communicated between the particles. This isn't something you could set up in your living room, but quantum entanglement is happening spontaneously all around us. The phenomenon will be exploited in quantum computers and may one day facilitate *Star Trek*-style teleportation.

Sam Edge
Ringwood, Hampshire, UK

Entangling photons is a matter of getting them to share some state before being separated, as a result of them interacting with either each other or a shared apparatus, such as a diffraction grating – a structure that diffracts light into several beams.

You are entangling photons all the time at home with every biochemical and electrical activity your body and belongings perform. However, these photons remain entangled for such a short period of time that you don't notice.



STANCA SANDA/ALAMY

This week's new questions

Solar dive **If you were to fall into the sun (and magically survive), what would you hear on the journey?** ***Marthinus Roos****, Elgin, Moray, UK*

Green goodbye **How can I ensure that most of my body is used after my death and what is left can be turned into something like compost?** ***Georgina Seaman****, Newbury, Berkshire, UK*

If you could fall into the sun without dying, what sounds might you hear?

Chilling chords

Why do some pieces of music give us goosebumps? Is it indicative of particular personal traits?

Hillary Shaw
Newport, Shropshire, UK

Some people get goosebumps from natural noises conveying danger, which are often high-pitched and discordant. These include the shriek of an angry animal, the creak of a tree branch about to fall and the howling of the wind. If you feed birds in the garden, you may hear them respond with a slightly higher, faster squawk to signal danger when you first go out and a slower, lower-pitched noise when they see you go back inside.

So, music with these "universal danger sounds" will give us goosebumps. We still like listening to it, just as we might like a horror film: it offers vicarious, danger-free thrills. And when we get scared in real life, we may make our own high-pitched sound – a scream – to relieve stress, a sort of emotional equivalent of noise-cancelling.

Simon McLeish
Lechlade, Gloucestershire, UK

Goosebumps are caused by the involuntary erection of hairs on the skin (piloerection) in response to a stimulus such as cold, but can also be triggered by strong or unexpected emotions. Magnetic resonance imaging (MRI) shows that music activates some of the same areas of the brain as sex and drugs, and it can cause a rush of dopamine that stimulates the body. But what is the evolutionary importance of this effect?

Musician David Huron has suggested this response to surprise was evolutionarily

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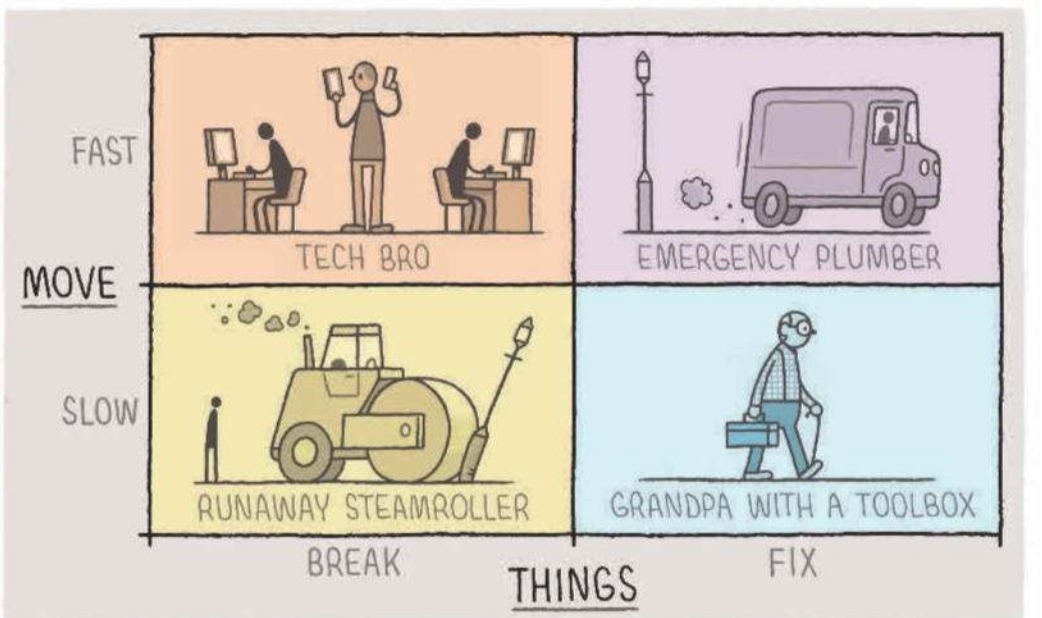
Tom Gauld
for New Scientist



important: the unexpected could be a threat to our prehistoric ancestors, and a quick response to sound could be life-saving.

This would suggest that the unexpected should be important in music, and it often is. While writing this, I was listening to *Abbey Road* by The Beatles. A very important part of the experience of that album are the contrasts between the different songs: the sequence from *Sun King* to *The End* is all built on the unexpected (and I still love it, even though I have now heard it hundreds of times).

Music appreciation is an intensely personal thing. One individual may have a strong reaction to a piece of music, but another may be left unmoved, even if it is the same recording.

Robin Maguire
Hobart, Tasmania, Australia

Autonomous sensory meridian response, or ASMR, is a pseudoscientific name given to a now-well-known phenomenon, characterised by the occasional sensation of a pleasant tingling.

"One individual may have a strong reaction to a piece of music, but another person who hears it may be left unmoved"

This would seem to have much in common with the goosebumps sometimes triggered by music.

Many people can induce a mild form of ASMR at will, and there are internet sites that offer sounds to prompt the sensation, such as whispering or crinkling paper. So, if you crave the effects of great music but tire of Bach and Mozart, a social media influencer stroking bubble wrap may work just as well.

Flat out

When a bubble, or spirit, level is level, what does that mean relative to Earth?

Michael Paine
Sydney, Australia

The situation is slightly more complicated than simply referring to the centre of gravity of Earth. That is because our planet has a huge satellite, the moon, and the two have a common centre of gravity about 4600 kilometres from Earth's true centre. The two bodies rotate around this barycentre, causing centripetal forces that depend on their distance from the common centre of gravity. This is one of the reasons why there are generally two ocean tides per day.

In the same way as water in the sea, the liquid in a spirit level is responding to the combined effects of Earth's gravity and the centripetal forces caused by this Earth-and-moon dance. Of course, as with tidal forces, the effects are negligible for everyday purposes.

John Welch
Sevenoaks, Kent, UK

If the gravitational effects of nearby mountains and of underground strata with different densities can be ignored, the spirit level is indicating the plane that is perpendicular to a line radiating from the centre of Earth. ▮

Answers

Quick quiz #297 *Answers*

1 Saturn

2 Hoglets

3 Betalain

4 Louis de Broglie

5 Gallium

Quick crossword #180 *Answers*

ACROSS 1 Mathematicians, **10** Octopus, **11** Air pump, **12** Admix, **13** Isolator, **15** Data access, **16** Acai, **18** Nits, **20** Riboflavin, **22** Theropod, **24** Wings, **26** Elevate, **27** Anergia, **28** Erythema solare

DOWN 2/9 Attempt no landing there, **3** Hypaxial, **4** Mass, **5** Transistor, **6** Coral, **7** Aquatic, **8** Supergiant star, **14** Echinoderm, **17** Flywheel, **19** Thereby, **21** Vinegar, **23** Orach, **25** Mars

#67 Pandigital sums *Solution*

There are four solutions to ABCD + EF = GHIJ where GHIJ = 2034. 1956 + 78, 1958 + 76, 1976 + 58 and 1978 + 56 all work.

There are 16 solutions to ABC + DEF = GHIJ where GHIJ = 1089.

The solution to ABC + DEF = GHIJ with A < B < C < D < E < F is 246 + 789 = 1035.

Whales not Wales

Feedback has been a science journalist for more years than we care to remember, and as a result we have come across our fair share of bizarre units of measurement. The human mind struggles with the very large and the very small, so as a writer it is tempting to say that huge icebergs have an area that is X times the size of Wales, or a mountain is Y times the height of the Burj Khalifa, or a bad book contains Z times more plot holes than *Fourth Wing*.

In this spirit, Christopher Dionne wrote in to highlight a CNN article about the Blue Ghost lunar lander sending its final message from the moon. He notes that the writer tries to convey the amount of data the probe sent by saying it "beamed a total of about 120 gigabytes of data – equivalent to more than 24,000 songs – back to Earth".

"This got me thinking," says Dionne. Nowadays a lot of music is streamed, so the size of the song files "doesn't generally matter". The size of the files will also vary depending on the compression method, and on a song's length. We can surely all agree that *All Too Well (10-minute Version)* is going to be a slightly larger file than *Love Me Do* – so you can't use songs as a standardised unit of dataset size.

Happily, Dionne has come up with a solution. "Why don't we use the internationally agreed upon standard of measurement – the blue whale?" The blue whale genome is 2.4 billion bases in length. "So it seems that the Blue Ghost has sent back 50 blue whales of data from the moon."

Feedback likes the idea, partly because we enjoy the Douglas-Adams-esque image of a torrent of whales hurtling to Earth from the moon. But we are going to quibble Dionne's maths. A base in a genome isn't equivalent to a byte in a dataset. Each byte is eight bits, and it is the bits that are analogous to bases. DNA isn't binary, either: there are four possible choices (A, C, G or T) for each position in the genome. That means you can encode a byte using half as many bases as bits. So, multiply by 8 and divide by 2, and we think Blue Ghost sent back about 200 blue whales.

We encourage readers to submit, as Dionne suggests, "other comparative units of digital measurement... which may be even better at communicating the scale of information", and we look forward to "a thoughtful discourse around this most pressing issue".

Twisteddoodles *for New Scientist*

Got a story for Feedback?
Send it to feedback@newscientist.com
or New Scientist, 9 Derry Street, London, W8 5HY
Consideration of items sent in the post will be delayed

Goodbye, Alice and Bob

Few things are more likely to kill a joke than the need to meticulously explain it. So Feedback is a bit nervous about this one, since it involves both a topical event and a cryptographic in-joke.

Let's start with the cryptography thing, because we think this is the one readers might need a refresher on. When explaining how secure messaging systems work, it has become traditional to refer to the two main agents as "Alice" and "Bob". For example: "How can Alice send a secure message to Bob using the Signal messaging app?"

The names have been in use since 1978 and are so widespread they have their own Wikipedia page. As well as describing the history of the device, this page delineates the hugely extended list of additional characters that can become involved in these thought experiments: from Chad, "a third participant, usually of malicious intent" all the way to Wendy, "a whistleblower".

Basically, if you are a regular *New Scientist* reader, you will probably have read stories that used Alice and Bob (and their friends/enemies/acquaintances/lovers) to explain complicated ideas in cryptography and physics. You are familiar with this. Parodies of it are therefore amusing.

We aren't going to bother naming the relevant news event. It was widely covered and discussed. Although, who knows: we are writing this on 27 March, so by the time you read this you might have forgotten about it, because the news moves so fast these days. Maybe the US has invaded Svalbard in the interim because Donald Trump forgot which Arctic landmass he wanted.

Anyway, here we go. Posting on Bluesky, software developer John VanEnk shared a screenshot of a Wikipedia page. It read: "Hegseth and Waltz are fictional characters commonly used as placeholders in discussions about cryptographic systems and protocols, and in other science and engineering literature where there are several participants in a thought experiment. The Hegseth and Waltz characters were created by Jeffrey Goldberg in his 2025 article 'The Trump Administration Accidentally Texted Me Its War Plans'. Subsequently, they have become common archetypes in many scientific and engineering fields..." This was accompanied by a diagram, described as an "example scenario where communication between Hegseth and Waltz is intercepted by Goldberg".

If, after all that buildup, you didn't find it funny, Feedback encourages you to send your comments to our Signal account, which we don't have.

What a lark

Readers Patrick Fenlon and Peter Slessenger both wrote in to highlight the same article in *The Guardian*, on how migrating birds use quantum mechanics to navigate. Apparently most "migrate at night and by themselves, so they have no one to follow", according to a biologist quoted in the article. Her name is Miriam Liedvogel, which of course means "songbird".

As Fenlon put it: "Wunderbar".

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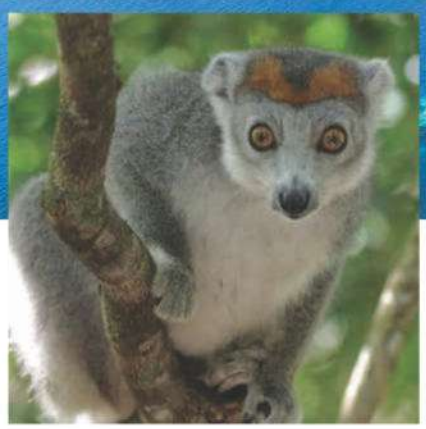

Unique ecosystems in the land of the lemur: Madagascar

3 September 2025
16 days

Be immersed in Madagascar's diverse and unique ecosystems, a living laboratory of evolution and biodiversity. Gain a deeper understanding of how, having broken away from mainland Africa some 150 million years ago, the country's rich flora and fauna have evolved in isolation, leading to unique adaptations and species found nowhere else on Earth.

- Discover the evolution of Madagascar's array of species and uncover its rich flora and fauna including lemurs and fossa
- Walk through endemic forests and rainforests and listen out for the haunting call of an indri (the largest species of lemur) or see a chameleon blending into its surroundings
- Learn how ongoing conservation work is crucial for understanding and protecting these irreplaceable ecosystems

Alfred Russel Wallace expedition cruise, Indonesia

23 January 2026
13 days

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- Explore primary rainforests, marine ecosystems and their flora and fauna, including several species of birds of paradise and Wallace's golden birdwing butterfly
- Go in search of wildlife aboard a 22-berth, luxury schooner and enjoy the beautiful marine habitats by kayak, paddle board and snorkelling
- Gain an in-depth insight into the life and work of Wallace, plus the natural treasures of Indonesia

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